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⁂

ASME B31.1 (2007), Code for Pressure Piping, Section on Power Piping, 2008 Addenda, as required by the laws of the States of Arizona, Alaska, Colorado, Illinois, Iowa, Kansas, Michigan, Missouri, Minnesota, Nebraska, Nevada, North Dakota, Ohio, Oregon, Wisconsin, et. alia.

ASME B31.1a-2008

Addenda to ASME B31.1-2007

Power Piping

ASME Code for Pressure Piping, B31

AN AMERICAN NATIONAL STANDARD

The American Society of
Mechanical Engineers
Three Park Avenue • New York, NY 10016

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ASME B31.1a-2008

Following approval by the B31 Committee and ASME, and after public review, ASME B31.1a-2008 was approved by the American National Standards Institute on March 3, 2008.

Addenda to ASME B31.1-2007 are issued in the form of replacement pages. Revisions, additions, and deletions are incorporated directly into the affected pages. It is advisable, however, that this page, the Addenda title and copyright pages, and all replaced pages be retained for reference.

SUMMARY OF CHANGES

This is the first Addenda to be published to ASME B31.1-2007.

Replace or insert the pages listed. Changes given below are identified on the pages by a margin note, **(A08)**, placed next to the affected area. Revisions introduced in ASME B31.1-2007 are indicated by **(07)**. The pages not listed are the reverse sides of the listed pages and contain no changes.

Page	*Location*	*Change*
vii–ix	Committee Roster	Updated
3	Fig. 100.1.2(B)	(1) In left half of drawing, near para. 122.1.7(D) callouts, two circles indicating jurisdiction and responsibility corrected by errata to be open (2) In right half of drawing, two references to para. 122.1.7 deleted and new one added by errata
10, 10.1	101.2.5	Added
13	Equation (2)	Equation and its nomenclature revised
16–16.2	102.4.7	Added
	104.1.1	Added
	104.1.2	Title revised
	Table 102.4.7	Added
18, 18.1	104.1.4	Added
19	104.3.1(D.2)	(1) D_o deleted (2) D_{ob} and D_{oh} added
23	104.3.1(G.4)	Revised
	104.3.1(G.5)	Revised
24	Fig. 104.3.1(G)	Callouts revised
41, 42	119.10.1	Nomenclature for E_c and E_h revised
50	Fig. 122.1.7(C)	Callouts revised
62, 62.1	123.2.2(C)	Added
	123.4	Added

Page	Location	Change
	124.4	In text table, for last three entries, cross-references corrected by errata
	124.5	In text table, for last three entries, cross-references corrected by errata
63	124.6(C)	In text table, for sixth through eighth entries, cross-references corrected by errata
67	Table 126.1	(1) Under Forgings, for ASTM B 462, title revised (2) Under Seamless Pipe and Tube, ASTM B 690 added
68	Table 126.1	(1) Under Welded Pipe and Tube, second entry corrected by errata to read B 608 (2) ASTM B 675, B 676, and B 804 added (3) Under Plate, Sheet, and Strip, ASTM B 171 added, B 402 deleted, and B 688 added (4) Under Rods, Bars, and Shapes, ASTM B 691 added
70	Table 126.1	Under National Fire Codes, NFPA 54/ANSI Z223.1 added, NFPA 85 added, NFPA 1963 revised, and NFPA 8503 deleted
75	127.4.3	Revised
80	127.5.3(B)	Last paragraph revised
87–88.1	Table 132	P-No. 5B revised
93	Table 136.4	General Note (f) added
118	Table A-2	Under Electric Fusion Welded Pipe — Filler Metal Added, for both A 691 Grade 91 lines, Note (17) references deleted by errata
132, 133	Table A-3	Under Seamless Pipe and Tube, Ferritic/Austenitic, A 789 and A 790 S32205 and S32750 added
138, 139	Table A-3	Under Welded Pipe and Tube — Without Filler Metal, Ferritic/Austenitic, A 789 and A 790 S32205 and S32750 added
144, 145	Table A-3	Under Plate, Sheet, and Strip, Ferritic/Austenitic, A 240 S32205 and S32750 added
148, 149	Table A-3	Under Forgings, Ferritic/Austenitic, A 182 Grades F60 and F53 added
150, 151	Table A-3	Under Fittings, Ferritic/Austenitic, A 815 S32205 added
154, 155	Table A-3	Under Bolts, Nuts, and Studs, Austenitic, for A 453 Grade 660, stress values for 200°F through 1,000°F added

Page	*Location*	*Change*
158	Table A-3	Note (39) added
160–169	Table A-4	Under Seamless Pipe and Tube, two B 690 N08367 lines revised and two added
	Table A-4	Under Welded Pipe and Tube, two B 675 N08367 lines revised and two added
	Table A-4	Two B 676 N08367 lines revised and two added
	Table A-4	Two B 804 N08367 lines revised and two added
	Table A-4	(1) Under Plate, Sheet, and Strip, first two B 688 N08367 lines deleted (2) For four remaining B 688 N08367 lines, Temper or Condition, Nominal Composition, and Notes revised
	Table A-4	Under Bars, Rods, Shapes, and Forgings, for both B 564 N08367 lines, Temper or Condition, Nominal Composition, and Notes revised
	Table A-4	For both B 691 N08367 lines, Temper or Condition, Nominal Composition, and Notes revised
	Table A-4	Under Seamless Fittings, for both B 462 N08367 lines, Temper or Condition, Nominal Composition, and Notes revised
	Table A-4	Under Welded Fittings, two B 366 N08367 lines added
170	Table A-4	Notes (21) and (22) added
174, 175	Table A-6	Under Seamless Pipe and Tube, for second B 42 line, Size or Thickness revised
	Table A-6	For third B 42 line, Size or Thickness and stress value for 250°F revised
	Table A-6	For B 111 C60800, stress value for 350°F revised
	Table A-6	For B 280 C12200 Annealed, stress value for 200°F revised
	Table A-6	For B 466 C71500, stress values for 650°F and 700°F added
	Table A-6	Under Welded Pipe and Tube, for B 608, stress line revised
176, 177	Table A-6	(1) Under Plate, for C70600 Annealed and both C71500 lines, B 402 replaced by B 171 (2) Line for C70600 Hot rolled added

Page	*Location*	*Change*
		(3) For first C71500 line, stress values for 750°F and 800°F deleted
	Table A-6	Under Rod and Bar, for B 151 C71500, stress values for 650°F and 700°F added
	Table A-6	Under Castings, for B 148 C95200, stress value for 500°F revised, and values for 550°F and 600°F added
	Table A-6	For B 148 C95400, stress values for 550°F and 600°F added
205	Table C-1 (SI)	In column heads, top line revised
208, 209	Table C-2 (SI)	In column heads, top line revised
217–219	Mandatory Appendix F	(1) ASTM A 182/A 182M, A 240/A 240M, A 789/A 789M, A 790/A 790M, A 815, and B 462 revised (2) ASTM B 171, B 675, B 676, B 688, B 690, B 691, and B 804 added (3) NFPA 54/ANSI Z223.1 and NFPA 85 added (4) NFPA 1963 revised (5) NFPA 8503 deleted
220–226	Mandatory Appendix G	(1) Previous second D symbol replaced by d_i (2) For D_o and D_{ob}, references revised (3) For D_{oh}, definition and references revised (4) Previous second d entry deleted (5) For second E, SI units revised (6) Previous first r symbol replaced by q (7) For second R, references revised (8) W added
264	Table III-4.3.1	Revised in its entirety
265	Table III-4.3.2	Revised in its entirety
297	Index	For flexible hose, nonmetallic, entry corrected by errata to read 105.3(D)
298	Index	For pressure, reducing valves, first entry corrected by errata to read 107.1(F)
300	Index	For valves, pressure regulator, entry corrected by errata to read 107.1(F)

SPECIAL NOTE:

The interpretations to ASME B31.1 issued between January 1, 2007 and December 31, 2007 follow the last page of this Addenda as a separate supplement, Interpretations Volume 43. After the Interpretations, a separate supplement, Cases No. 33, follows.

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Code for Pressure Piping

(A08)

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INTRODUCTION

The ASME B31 Code for Pressure Piping consists of a number of individually published Sections, each an American National Standard, under the direction of ASME Committee B31, Code for Pressure Piping.

Rules for each Section have been developed considering the need for application of specific requirements for various types of pressure piping. Applications considered for each Code Section include:

B31.1 Power Piping: piping typically found in electric power generating stations, in industrial and institutional plants, geothermal heating systems, and central and district heating and cooling systems;

B31.3 Process Piping: piping typically found in petroleum refineries, chemical, pharmaceutical, textile, paper, semiconductor, and cryogenic plants, and related processing plants and terminals;

B31.4 Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids: piping transporting products which are predominately liquid between plants and terminals and within terminals, pumping, regulating, and metering stations;

B31.5 Refrigeration Piping: piping for refrigerants and secondary coolants;

B31.8 Gas Transportation and Distribution Piping Systems: piping transporting products which are predominately gas between sources and terminals, including compressor, regulating, and metering stations; and gas gathering pipelines;

B31.9 Building Services Piping: piping typically found in industrial, institutional, commercial, and public buildings, and in multi-unit residences, which does not require the range of sizes, pressures, and temperatures covered in B31.1;

B31.11 Slurry Transportation Piping Systems: piping transporting aqueous slurries between plants and terminals and within terminals, pumping, and regulating stations.

This is the B31.1 Power Piping Code Section. Hereafter, in this Introduction and in the text of this Code Section B31.1, where the word *Code* is used without specific identification, it means this Code Section.

It is the owner's responsibility to select the Code Section which most nearly applies to a proposed piping installation. Factors to be considered by the owner include: limitations of the Code Section, jurisdictional requirements, and the applicability of other codes and standards. All applicable requirements of the selected Code Section shall be met. For some installations, more than one Code Section may apply to different parts of the installation. The owner is also responsible for imposing requirements supplementary to those of the selected Code Section, if necessary, to assure safe piping for the proposed installation.

Certain piping within a facility may be subject to other codes and standards, including but not limited to:

ASME Boiler and Pressure Vessel Code, Section III: nuclear power piping;

ANSI Z223.1 National Fuel Gas Code: piping for fuel gas from the point of delivery to the connection of each fuel utilization device;

NFPA Fire Protection Standards: fire protection systems using water, carbon dioxide, halon, foam, dry chemical, and wet chemicals;

NFPA 99 Health Care Facilities: medical and laboratory gas systems;

NFPA 8503 Standard for Pulverized Fuel Systems: piping for pulverized coal from the coal mills to the burners;

Building and plumbing codes, as applicable, for potable hot and cold water, and for sewer and drain systems.

The Code sets forth engineering requirements deemed necessary for safe design and construction of pressure piping. While safety is the basic consideration, this factor alone will not necessarily govern the final specifications for any piping system. The designer is cautioned that the Code is not a design handbook; it does not do away with the need for the designer or for competent engineering judgment.

To the greatest possible extent, Code requirements for design are stated in terms of basic design principles and formulas. These are supplemented as necessary with specific requirements to assure uniform application of principles and to guide selection and application of piping elements. The Code prohibits designs and practices known to be unsafe and contains warnings where caution, but not prohibition, is warranted.

The specific design requirements of the Code usually revolve around a simplified engineering approach to a subject. It is intended that a designer capable of applying more complete and rigorous analysis to special or unusual problems shall have latitude in the development of such designs and the evaluation of complex or combined stresses. In such cases the designer is responsible for demonstrating the validity of his approach.

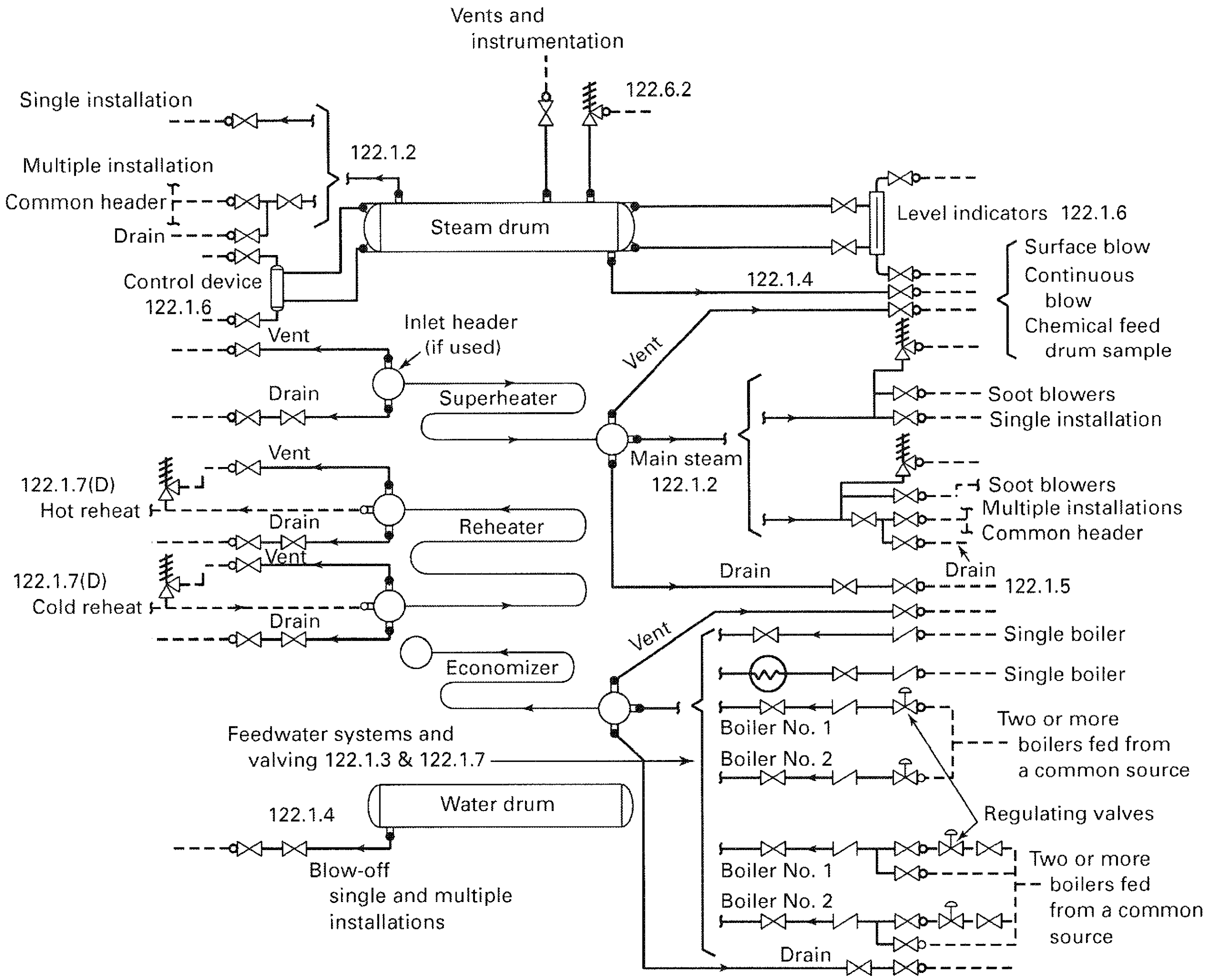
This Code Section includes the following:

(a) references to acceptable material specifications and component standards, including dimensional requirements and pressure-temperature ratings

(b) requirements for design of components and assemblies, including pipe supports

Fig. 100.1.2(B) Code Jurisdictional Limits for Piping — Drum-Type Boilers

(A08)



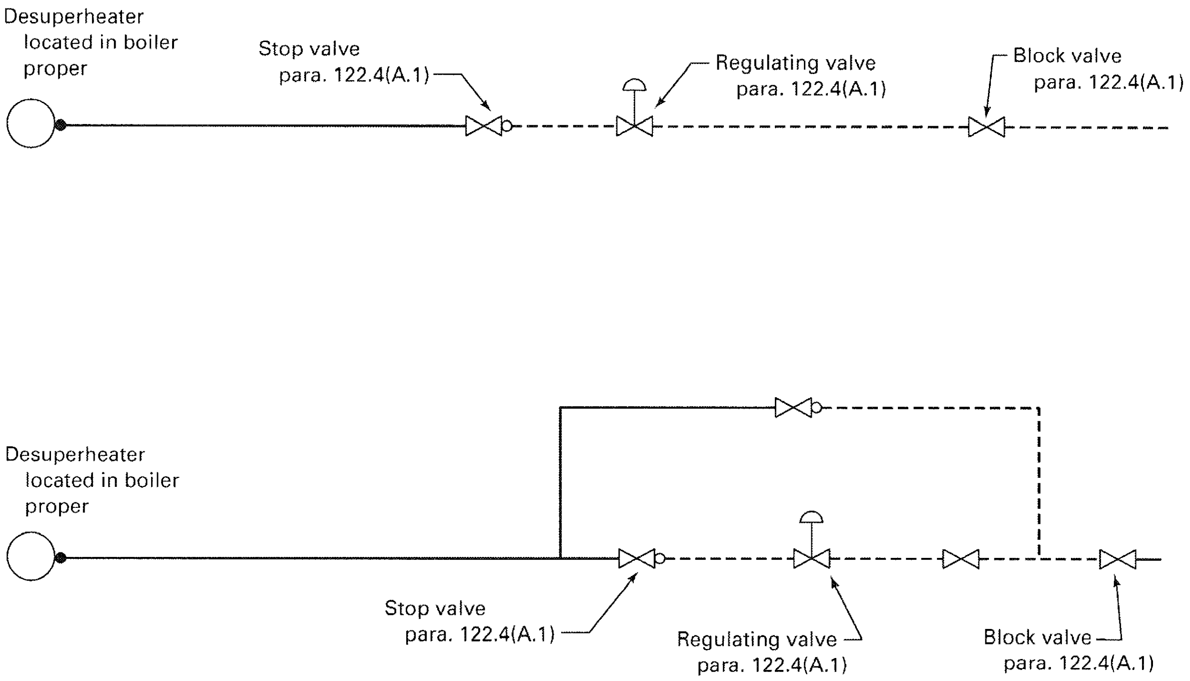
Administrative Jurisdiction and Technical Responsibility

——— Boiler Proper — The ASME Boiler and Pressure Vessel Code (ASME BPVC) has total administrative jurisdiction and technical responsibility. Refer to ASME BPVC Section I Preamble.

•——— Boiler External Piping and Joint (BEP) — The ASME BPVC has total administrative jurisdiction (mandatory certification by Code Symbol stamping, ASME Data Forms, and Authorized Inspection) of BEP. The ASME Section Committee B31.1 has been assigned technical responsibility. Refer to ASME BPVC Section I Preamble and ASME B31.1 Scope, para. 100.1.2(A). Applicable ASME B31.1 Editions and Addenda are referenced in ASME BPVC Section I, PG-58.3.

○- - - - - Nonboiler External Piping and Joint (NBEP) — The ASME Code Committee for Pressure Piping, B31, has total administrative jurisdiction and technical responsibility.

Fig. 100.1.2(C) Code Jurisdictional Limits for Piping — Spray-Type Desuperheater


Desuperheater located in boiler proper
Stop valve para. 122.4(A.1)
Regulating valve para. 122.4(A.1)
Block valve para. 122.4(A.1)
Desuperheater located in boiler proper
Stop valve para. 122.4(A.1)
Regulating valve para. 122.4(A.1)
Block valve para. 122.4(A.1)

Administrative Jurisdiction and Technical Responsibility

——— Boiler Proper — The ASME Boiler and Pressure Vessel Code (ASME BPVC) has total administrative jurisdiction and technical responsibility. Refer to ASME BPVC Section 1 Preamble.

●——— Boiler External Piping and Joint (BEP) — The ASME BPVC has total administrative jurisdiction (mandatory certification by Code Symbol stamping, ASME Data Forms, and Authorized Inspection) of BEP. The ASME Section Committee B31.1 has been assigned technical responsibility. Refer to ASME BPVC Section I Preamble and ASME B31.1 Scope, para. 100.1.2(A). Applicable ASME B31.1 Editions and Addenda are referenced in ASME BPVC Section I, PG-58.3.

○- - - - Nonboiler External Piping and Joint (NBEP) — The ASME Code Committee for Pressure Piping, B31, has total administrative and technical responsibility.

steel: an alloy of iron and carbon with no more than 2% carbon by weight. Other alloying elements may include manganese, sulfur, phosphorus, silicon, aluminum, chromium, copper, nickel, molybdenum, vanadium, and others depending upon the type of steel. For acceptable material specifications for steel, refer to Chapter III, Materials.

stresses

displacement stress: a stress developed by the self-constraint of the structure. It must satisfy an imposed strain pattern rather than being in equilibrium with an external load. The basic characteristic of a displacement stress is that it is self-limiting. Local yielding and minor distortions can satisfy the displacement or expansion conditions which cause the stress to occur. Failure from one application of the stress is not to be expected. Further, the displacement stresses calculated in this Code are "effective" stresses and are generally lower than those predicted by theory or measured in strain-gage tests.[1]

peak stress: the highest stress in the region under consideration. The basic characteristic of a peak stress is that it causes no significant distortion and is objectionable only as a possible source of a fatigue crack initiation or a brittle fracture. This Code does not utilize peak stress as a design basis, but rather uses effective stress values for sustained stress and for displacement stress; the peak stress effect is combined with the displacement stress effect in the displacement stress range calculation.

sustained stress: a stress developed by an imposed loading which is necessary to satisfy the laws of equilibrium between external and internal forces and moments. The basic characteristic of a sustained stress is that it is not self-limiting. If a sustained stress exceeds the yield strength of the material through the entire thickness, the prevention of failure is entirely dependent on the strain-hardening properties of the material. A thermal stress is not classified as a sustained stress. Further, the sustained stresses calculated in this Code are "effective" stresses and are generally lower than those predicted by theory or measured in strain-gage tests.

stress-relieving: see *heat treatments.*

submerged arc welding: an arc welding process wherein coalescence is produced by heating with an electric arc or arcs between a bare metal electrode or electrodes and the work. The welding is shielded by a blanket of granular, fusible material on the work. Pressure is not used, and filler metal is obtained from the electrode and sometimes from a supplementary welding rod.

supplementary steel: steel members which are installed between existing members for the purpose of installing supports for piping or piping equipment.

swivel joint: a component which permits single-plane rotational movement in a piping system.

tack weld: a weld made to hold parts of a weldment in proper alignment until the final welds are made.

throat of a fillet weld

actual: the shortest distance from the root of a fillet weld to its face.

theoretical: the distance from the beginning of the root of the joint perpendicular to the hypotenuse of the largest right triangle that can be inscribed within the fillet weld cross section.

toe of weld: the junction between the face of the weld and the base metal.

tube: refer to *pipe and tube.*

tungsten electrode: a nonfiller metal electrode used in arc welding, consisting of a tungsten wire.

undercut: a groove melted into the base metal adjacent to the toe of a weld and not filled with weld metal.

visual examination: the observation of whatever portions of components, joints, and other piping elements that are exposed to such observation either before, during, or after manufacture, fabrication, assembly, erection, inspection, or testing. This examination may include verification of the applicable requirements for materials, components, dimensions, joint preparation, alignment, welding or joining, supports, assembly, and erection.

weld: a localized coalescence of metal which is produced by heating to suitable temperatures, with or without the application of pressure, and with or without the use of filler metal. The filler metal shall have a melting point approximately the same as the base metal.

welder: one who is capable of performing a manual or semiautomatic welding operation.

Welder/Welding Operator Performance Qualification (WPQ): demonstration of a welder's ability to produce welds in a manner described in a Welding Procedure Specification that meets prescribed standards.

welding operator: one who operates machine or automatic welding equipment.

Welding Procedure Specification (WPS): a written qualified welding procedure prepared to provide direction for making production welds to Code requirements. The WPS or other documents may be used to provide direction to the welder or welding operator to assure compliance with the Code requirements.

weldment: an assembly whose component parts are joined by welding.

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[1] Normally, the most significant displacement stress is encountered in the thermal expansion stress range from ambient to the normal operating condition. This stress range is also the stress range usually considered in a flexibility analysis. However, if other significant stress ranges occur, whether they are displacement stress ranges (such as from other thermal expansion or contraction events, or differential support movements) or sustained stress ranges (such as from cyclic pressure, steam hammer, or earthquake inertia forces), paras. 102.3.2(B) and 104.8.3 may be used to evaluate their effect on fatigue life.

Chapter II
Design

PART 1
CONDITIONS AND CRITERIA

101 DESIGN CONDITIONS

101.1 General

These design conditions define the pressures, temperatures and various forces applicable to the design of power piping systems. Power piping systems shall be designed for the most severe condition of coincident pressure, temperature and loading, except as herein stated. The most severe condition shall be that which results in the greatest required pipe wall thickness and the highest flange rating.

101.2 Pressure

All pressures referred to in this Code are expressed in pounds per square inch and kilopascals above atmospheric pressure, i.e., psig [kPa (gage)], unless otherwise stated.

101.2.2 Internal Design Pressure. The internal design pressure shall be not less than the maximum sustained operating pressure (MSOP) within the piping system including the effects of static head.

101.2.4 External Design Pressure. Piping subject to external pressure shall be designed for the maximum differential pressure anticipated during operating, shutdown, or test conditions.

(A08) **101.2.5 Pressure Cycling.** This Code does not address the contribution to fatigue in fittings and components caused by pressure cycling. Special consideration may be necessary where systems are subjected to a very high number of large pressure cycles.

101.3 Temperature

101.3.1 All temperatures referred to in this Code, unless otherwise stated, are the average metal temperatures of the respective materials expressed in degrees Fahrenheit, i.e., °F (Celsius, i.e., °C).

101.3.2 Design Temperature

(A) The piping shall be designed for a metal temperature representing the maximum sustained condition expected. The design temperature shall be assumed to be the same as the fluid temperature unless calculations or tests support the use of other data, in which case the design temperature shall not be less than the average of the fluid temperature and the outside wall temperature.

(B) Where a fluid passes through heat exchangers in series, the design temperature of the piping in each section of the system shall conform to the most severe temperature condition expected to be produced by the heat exchangers in that section of the system.

(C) For steam, feedwater, and hot water piping leading from fired equipment (such as boiler, reheater, superheater, economizer, etc.), the design temperature shall be based on the expected continuous operating condition plus the equipment manufacturers guaranteed maximum temperature tolerance. For operation at temperatures in excess of this condition, the limitations described in para. 102.2.4 shall apply.

(D) Accelerated creep damage, leading to excessive creep strains and potential pipe rupture, caused by extended operation above the design temperature shall be considered in selecting the design temperature for piping to be operated above 800°F (425°C).

101.4 Ambient Influences

101.4.1 Cooling Effects on Pressure. Where the cooling of a fluid may reduce the pressure in the piping to below atmospheric, the piping shall be designed to withstand the external pressure or provision shall be made to break the vacuum.

101.4.2 Fluid Expansion Effects. Where the expansion of a fluid may increase the pressure, the piping system shall be designed to withstand the increased pressure or provision shall be made to relieve the excess pressure.

101.5 Dynamic Effects

101.5.1 Impact. Impact forces caused by all external and internal conditions shall be considered in the piping design. One form of internal impact force is due to the propagation of pressure waves produced by sudden changes in fluid momentum. This phenomena is often called water or steam "hammer." It may be caused by the rapid opening or closing of a valve in the system. The designer should be aware that this is only one example of this phenomena and that other causes of impact loading exist.

101.5.2 Wind. Exposed piping shall be designed to withstand wind loadings, using meteorological data to determine wind forces. Where state or municipal ordinances covering the design of building structures are in effect and specify wind loadings, these values shall be considered the minimum design values.

101.5.3 Earthquake. The effect of earthquakes, where applicable, shall be considered in the design of piping, piping supports, and restraints, using data for

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f is 0.15, which results in an allowable displacement stress range for a total number of equivalent reference displacement stress range cycles greater than 10^8 cycles.

S_c = basic material allowable stress from Appendix A at the minimum metal temperature expected during the reference stress range cycle, psi (kPa)[2]

S_h = basic material allowable stress from Appendix A at the maximum metal temperature expected during the reference stress range cycle, psi (kPa)[2]

In determining the basic material allowable stresses, S_c and S_h, for welded pipe, the joint efficiency factor, E, need not be applied (see para. 102.4.3). The values of the allowable stresses from Appendix A may be divided by the joint efficiency factor given for that material. In determining the basic material allowable stresses for castings, the casting quality factor, F, shall be applied (see para. 102.4.6).

When considering more than a single displacement stress range, whether from thermal expansion or other cyclic conditions, each significant stress range shall be computed. The reference displacement stress range, S_E, is defined as the greatest computed displacement stress range. The total number of reference displacement stress range cycles, N, may then be calculated by eq. (2)

(A08)

$$N = N_E + \Sigma(q_i^5 N_i) \text{ for } i = 1, 2, \ldots, n \tag{2}$$

where

N_E = number of cycles of the reference displacement stress range, S_E

N_i = number of cycles associated with displacement stress range, S_i

q_i = S_i/S_E

S_i = any computed stress range other than the reference displacement stress range, psi (kPa)

102.3.3 Limits of Calculated Stresses Due to Occasional Loads

(A) During Operation. The sum of the longitudinal stresses produced by internal pressure, live and dead loads and those produced by occasional loads, such as the temporary supporting of extra weight, may exceed the allowable stress values given in the Allowable Stress Tables by the amounts and durations of time given in para. 104.8.2.

(B) During Test. During pressure tests performed in accordance with para. 137, the circumferential (hoop) stress shall not exceed 90% of the yield strength (0.2% offset) at test temperature. In addition, the sum of longitudinal stresses due to test pressure and live and dead loads at the time of test, excluding occasional loads, shall not exceed 90% of the yield strength at test temperature.

102.4 Allowances

102.4.1 Corrosion or Erosion. When corrosion or erosion is expected, an increase in wall thickness of the piping shall be provided over that required by other design requirements. This allowance in the judgment of the designer shall be consistent with the expected life of the piping.

102.4.2 Threading and Grooving. The calculated minimum thickness of piping (or tubing) which is to be threaded shall be increased by an allowance equal to thread depth; dimension h of ASME B1.20.1 or equivalent shall apply. For machined surfaces or grooves, where the tolerance is not specified, the tolerance shall be assumed to be $\frac{1}{64}$ in. (0.40 mm) in addition to the specified depth of cut. The requirements of para. 104.1.2(C) shall also apply.

102.4.3 Weld Joint Efficiency Factors. The use of joint efficiency factors for welded pipe is required by this Code. The factors in Table 102.4.3 are based on full penetration welds. These factors are included in the allowable stress values given in Appendix A. The factors in Table 102.4.3 apply to both straight seam and spiral seam welded pipe.

102.4.4 Mechanical Strength. Where necessary for mechanical strength to prevent damage, collapse, excessive sag, or buckling of pipe due to superimposed loads from supports or other causes, the wall thickness of the pipe should be increased; or, if this is impractical or would cause excessive local stresses, the superimposed loads or other causes shall be reduced or eliminated by other design methods. The requirements of para. 104.1.2(C) shall also apply.

102.4.5 Bending. The minimum wall thickness at any point on the bend shall conform to (A) or (B) below.

(A) The minimum wall thickness at any point in a completed bend shall not be less than required by eq. (3) or (3A) of para. 104.1.2(A).

(A.1) Table 102.4.5 is a guide to the designer who must specify wall thickness for ordering pipe. In general, it has been the experience that when good shop practices are employed, the minimum thicknesses of straight pipe shown in Table 102.4.5 should be sufficient for bending and still meet the minimum thickness requirements of para. 104.1.2(A).

(A.2) The bend thinning allowance in Table 102.4.5 may be provided in all parts of the cross section of the pipe circumference without any detrimental effects being produced.

(B) The minimum required thickness, t_m, of a bend, after bending, in its finished form, shall be determined in accordance with eq. (3B) or (3C) **(07)**

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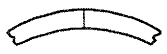
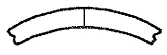
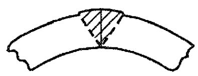
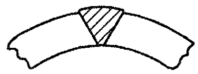
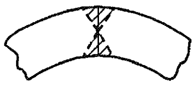
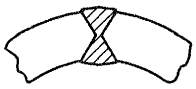
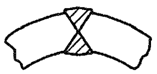
[2] For materials with a minimum tensile strength of over 70 ksi (480 MPa), eqs. (1A) and (1B) shall be calculated using S_c or S_h values no greater than 20 ksi (140 MPa), unless otherwise justified.

Table 102.4.3 Longitudinal Weld Joint Efficiency Factors

No.	Type of Joint	Type of Seam	Examination	Factor E
1	Furnace butt weld, continuous weld 	Straight	As required by listed specification	0.60 [Note (1)]
2	Electric resistance weld 	Straight or spiral	As required by listed specification	0.85 [Note (1)]
3	Electric fusion weld			
	(a) Single butt weld (without filler metal) 	Straight or spiral	As required by listed specification	0.85
			Additionally 100% radiographed	1.00 [Note (2)]
	(b) Single butt weld (with filler metal) 	Straight or spiral	As required by listed specification	0.80
			Additionally 100% radiographed	1.00 [Note (2)]
	(c) Double butt weld (without filler metal) 	Straight or spiral	As required by listed specification	0.90
			Additionally 100% radiographed	1.00 [Note (2)]
	(d) Double butt weld (with filler metal) 	Straight or spiral	As required by listed specification	0.90
			Additionally 100% radiographed	1.00 [Note (2)]
4	API 5L Submerged arc weld (SAW) Gas metal arc weld (GMAW) Combined GMAW, SAW 	Straight with one or two seams Spiral	As required by specification	0.90
			Additionally 100% radiographed	1.00 [Note (2)]

NOTES:
(1) It is not permitted to increase the longitudinal weld joint efficiency factor by additional examination for joint 1 or 2.
(2) Radiography shall be in accordance with the requirements of para. 136.4.5 or the material specification, as applicable.

$$t_m = \frac{PD_o}{2(SE/I + Py)} + A \tag{3B}$$

or

$$t_m = \frac{Pd + 2SEA/I + 2yPA}{2(SE/I + Py - P)} \tag{3C}$$

where at the intrados (inside of bend)

$$I = \frac{4(R/D_o) - 1}{4(R/D_o) - 2} \tag{3D}$$

and at the extrados (outside of bend)

$$I = \frac{4(R/D_o) + 1}{4(R/D_o) + 2} \tag{3E}$$

and at the sidewall on the bend centerline, $I = 1.0$ where
R = bend radius of pipe bend

Thickness variations from the intrados to the extrados and at the ends of the bend shall be gradual. The thickness requirements apply at the center of the bend arc, at the intrados, extrados, and bend centerline (see Fig. 102.4.5). The minimum thickness at the ends of the bends shall not be less than the requirements of para. 104.1.2 for straight pipe. For bends to conform to this paragraph, all thickness requirements must be met.

102.4.6 Casting Quality Factors

(A) General. The use of a casting quality factor is required for all cast components which use the allowable

Table 102.4.5 Bend Thinning Allowance

Radius of Bends	Minimum Thickness Recommended Prior to Bending
6 pipe diameters or greater	$1.06t_m$
5 pipe diameters	$1.08t_m$
4 pipe diameters	$1.14t_m$
3 pipe diameters	$1.25t_m$

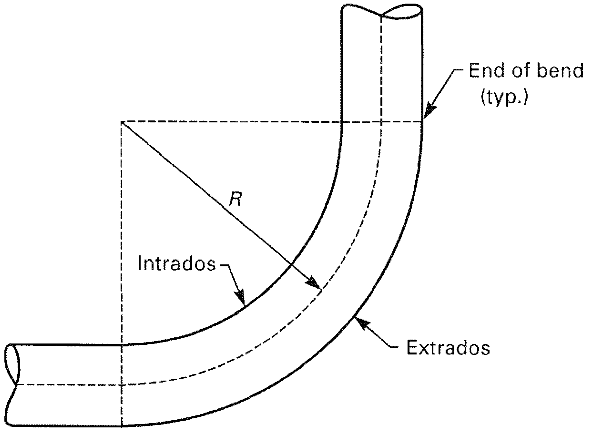
GENERAL NOTES:

(a) Interpolation is permissible for bending to intermediate radii.

(b) t_m is determined by eq. (3) or (3A) of para. 104.1.2(A).

(c) Pipe diameter is the nominal diameter as tabulated in ASME B36.10M, Tables 1, and ASME B36.19M, Table 1. For piping with a diameter not listed in these Tables, and also for tubing, the nominal diameter corresponds with the outside diameter.

(07) **Fig. 102.4.5 Nomenclature for Pipe Bends**



stress values of Appendix A as the design basis. A factor of 0.80 is included in the allowable stress values for all castings given in Appendix A.

This required factor does not apply to component standards listed in Table 126.1, if such standards define allowable pressure–temperature ratings or provide the allowable stresses to be used as the design basis for the component.

(B) For steel materials, a casting quality factor not exceeding 1.0 may be applied when the following requirements are met:

(B.1) All steel castings having a nominal body thickness of $4\frac{1}{2}$ in. (114 mm) or less (other than pipe flanges, flanged valves and fittings, and butt welding end valves, all complying with ASME B16.5 or B16.34) shall be inspected as follows:

(B.1.1) All critical areas, including the junctions of all gates, risers, and abrupt changes in section or direction and area of weld end preparation shall be radiographed in accordance with Article 2 of Section V of the ASME Boiler and Pressure Vessel Code, and the radiographs shall conform to the requirements of ASTM E 446, Reference Radiographs for Steel Castings up to 2 in. (50 mm) in Thickness or E 186 Reference Radiographs for Heavy Walled [2 to $4\frac{1}{2}$ in. (50 to 114 mm)] Steel Castings, depending upon the section thickness. The maximum acceptable severity level for a 1.0 quality factor shall be as listed in Table 102.4.6(B.1.1).

(B.1.2) All surfaces of each casting, including machined gasket seating surfaces, shall be examined by the magnetic particle or dye penetrant method after heat treatment. The examination techniques shall be in accordance with Article 6 or 7, as applicable, and Article 9 of Section V of the ASME Boiler and Pressure Vessel Code. Magnetic particle or dye penetrant indications exceeding degree 1 of Type I, degree 2 of Type II, and degree 3 of Type III, and exceeding degree 1 of Types IV and V of ASTM E 125, Standard Reference Photographs for Magnetic Particle Indications on Ferrous Castings, are not acceptable and shall be removed.

(B.1.3) Where more than one casting of a particular design is produced, each of the first five castings shall be inspected as above. Where more than five castings are being produced, the examination shall be performed on the first five plus one additional casting to represent each five additional castings. If this additional casting proves to be unacceptable, each of the remaining castings in the group shall be inspected.

(B.1.4) Any discontinuities in excess of the maximum permitted in (B.1.1) and (B.1.2) above shall be removed, and the casting may be repaired by welding after the base metal has been inspected to assure complete removal of discontinuities. [Refer to para. 127.4.11(A).] The complete 4d repair shall be subject to reinspection by the same method as was used in the original inspection and shall be reinspected after any required postweld heat treatment.

(B.2) All steel castings having a nominal body thickness greater than $4\frac{1}{2}$ in. (114 mm) (other than pipe flanges, flanged valves and fittings, and butt welding end valves, all complying with ASME B16.5 or B16.34) shall be inspected as follows:

(B.2.1) All surfaces of each casting including machined gasket seating surfaces, shall be examined by the magnetic particle or dye penetrant method after heat treatment. The examination techniques shall be in accordance with Article 6 or 7, as applicable, and with Article 9 of Section V of the ASME Boiler and Pressure Vessel Code. Magnetic particle or dye penetrant indications exceeding degree 1 of Type I, degree 2 of Type II, degree 3 of Type III, and degree 1 of Types IV and V of ASTM E 125, Standard Reference Photographs for Magnetic Particle Indications on Ferrous Castings, shall be removed.

(B.2.2) All parts of castings shall be subjected to complete radiographic inspection in accordance with Article 2 of Section V of the ASME Boiler and Pressure

Table 102.4.6(B.1.1) Maximum Severity Level for Casting Thickness $4\frac{1}{2}$ in. (114 mm) or Less

Discontinuity Category Designation	Severity Level ≤1 in. (25 mm) Thick	Severity Level >1 in. (25 mm) Thick
For E 446 [Castings up to 2 in. (50 mm) Thickness]		
A	1	2
B	2	3
C Types 1, 2, 3, and 4	1	3
D, E, F, and G	None acceptable	None acceptable

Discontinuity Category Designation	Severity Level
For E 186 [Castings 2 in. to $4\frac{1}{2}$ in. (50 mm to 114 mm) Thickness]	
A, B, and Types 1 and 2 of C	2
Type 3 of C	3
D, E, and F	None acceptable

Table 102.4.6(B.2.2) Maximum Severity Level for Casting Thickness Greater Than $4\frac{1}{2}$ in. (114 mm)

Discontinuity Category Designation	Severity Level
A, B, and Types 1, 2, and 3 of C	2
D, E, and F	None acceptable

Vessel Code, and the radiographs shall conform to the requirements of ASTM E 280, Reference Radiographs for Heavy Walled [$4\frac{1}{2}$ to 12 in. (114 to 305 mm)] Steel Castings.

The maximum acceptable severity level for a 1.0 quality factor shall be as listed in Table 102.4.6(B.2.2).

(B.2.3) Any discontinuities in excess of the maximum permitted in (B.2.1) and (B.2.2) above shall be removed and may be repaired by welding after the base metal has been magnetic particle or dye penetrant inspected to assure complete removal of discontinuities. [Refer to para. 127.4.11(A).]

(B.2.4) All weld repairs of depth exceeding 1 in. (25 mm) or 20% of the section thickness, whichever is the lesser, shall be inspected by radiography in accordance with (B.2.2) above and by magnetic particle or dye penetrant inspection of the finished weld surface. All weld repairs of depth less than 20% of the section thickness, or 1 in. (25 mm), whichever is the lesser, and all weld repairs of section that cannot be effectively radiographed shall be examined by magnetic particle or dye penetrant inspection of the first layer, of each $\frac{1}{4}$ in. (6 mm) thickness of deposited weld metal, and of the finished weld surface. Magnetic particle or dye penetrant testing of the finished weld surface shall be done after postweld heat treatment.

(C) For cast iron and nonferrous materials, no increase of the casting quality factor is allowed except when special methods of examination, prescribed by the material specification, are followed. If such increase is specifically permitted by the material specification, a factor not exceeding 1.0 may be applied.

102.4.7 Weld Strength Reduction Factors. At elevated temperatures, seam welds on longitudinal-welded or spiral-welded pipe can have lower creep strength than the base material. This reduction is a factor in determining the minimum wall thickness for longitudinal-welded or spiral-welded pipe (i.e., not seamless), whether fabricated in accordance with a material specification or fabricated in accordance with the rules of this Code. The weld strength reduction factor, *W*, is given in Table 102.4.7. The designer is responsible to assess application of weld strength reduction factor requirements for welds other than longitudinal and spiral, as applicable (e.g., circumferential welds). (A08)

PART 2
PRESSURE DESIGN OF PIPING COMPONENTS

103 CRITERIA FOR PRESSURE DESIGN OF PIPING COMPONENTS

The design of piping components shall consider the effects of pressure and temperature, in accordance with paras. 104.1 through 104.7, including the consideration of allowances permitted by paras. 102.2.4 and 102.4. In addition, the mechanical strength of the piping system shall be determined adequate in accordance with para. 104.8 under other applicable loadings, including but not limited to those loadings defined in para. 101.

104 PRESSURE DESIGN OF COMPONENTS

104.1 Straight Pipe

104.1.1 Straight Pipe Under Internal Pressure. (A08) Straight pipe under internal pressure shall have a minimum wall thickness calculated per para. 104.1.2 if the pipe is of seamless construction or is designed for sustained operation below the creep range. Straight pipe under internal pressure shall have a minimum wall thickness calculated per para. 104.1.4 if the pipe is of longitudinal-welded or spiral-welded construction designed for sustained operation within the creep range. (See para. 123.4 for definition of the creep range.)

(A08) 104.1.2 Straight Pipe Under Internal Pressure — Seamless, Longitudinal Welded, or Spiral Welded and Operating Below the Creep Range

(A) Minimum Wall Thickness. The minimum thickness of pipe wall required for design pressures and for temperatures not exceeding those for the various materials listed in the Allowable Stress Tables, including allowances for mechanical strength, shall not be less than that determined by eq. (3) or (3A), as follows:

$$t_m = \frac{PD_o}{2(SE + Py)} + A \qquad (3)^3$$

$$t_m = \frac{Pd + 2SEA + 2yPA}{2(SE + Py - P)} \qquad (3A)^3$$

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[3] *SF* shall be used in place of *SE* where casting quality factors are intended. See definition of *SE*. Units of *P* and *SE* must be identical. Appendix A values must be converted to kPa when the design pressure is in kPa.

(A08) Table 102.4.7 Weld Strength Reduction Factors to Be Applied When Calculating the Minimum Wall Thickness or Allowable Design Pressure of Components Fabricated With a Longitudinal Seam Fusion Weld

	Weld Strength Reduction Factor for Temperature, °F (°C) [Notes (1)–(6)]										
Steel Group	700 (371)	750 (399)	800 (427)	850 (454)	900 (482)	950 (510)	1,000 (538)	1,050 (566)	1,100 (593)	1,150 (621)	1,200 (649)
Carbon (Norm.) [Notes (7), (8)]	1.00	0.95	0.91	NP	NP	NP	NP	NP	NP	NP	NP
Carbon (Sub Crit) [Notes (8), (9)]	1.00	0.95	0.91	NP	NP	NP	NP	NP	NP	NP	NP
CrMo [Notes (8), (10), (11)]	...	...	1.00	0.95	0.91	0.86	0.82	0.77	0.73	0.68	0.64
CSEF (N+T) [Notes (8), (12), (13)]	...	...	...	...	...	1.00	0.95	0.91	0.86	0.82	0.77
CSEF (Sub Crit) [Notes (8), (9)]	...	...	...	...	1.00	0.73	0.68	0.64	0.59	0.55	0.50
Austenitic stainless (incl. 800H & 800HT) [Notes (14), (15)]	...	...	...	...	...	1.00	0.95	0.91	0.86	0.82	0.77
Autogenously welded austenitic stainless [Note (16)]	...	...	...	...	...	1.00	1.00	1.00	1.00	1.00	1.00

NOTES:

(1) NP = not permitted.

(2) Longitudinal welds in pipe for materials not covered in this Table operating in the creep regime are not permitted. For the purposes of this Table, the start of the creep range is the highest temperature where the nonitalicized stress values end in Mandatory Appendix A for the base material involved.

(3) All weld filler metal shall be a minimum of 0.05% C for CrMo and CSEF materials, and 0.04% C for austenitic stainless in this Table.

(4) Materials designed for temperatures below the creep range [see Note (2)] may be used without consideration of the WSRF or the rules of this Table. All other Code rules apply.

(5) Longitudinal seam welds in CrMo and CSEF materials shall be subjected to, and pass, a 100% volumetric examination (RT or UT). For materials other than CrMo and CSEF, see para. 123.4(B).

(6) At temperatures below those where WSRFs are tabulated, a value of 1.0 shall be used for the factor *W* where required by the rules of this Section. However, the additional rules of this Table and Notes do not apply.

(7) Norm. = normalizing postweld heat treatment (PWHT) is required.

(8) Basicity index of SAW flux ≥ 1.0.

(9) Sub Crit = subcritical PWHT is required. No exemptions from PWHT are permitted. The PWHT time and temperature shall meet the requirements of Table 132; the alternate PWHT requirements of Table 132.1 are not permitted.

(10) The CrMo steels include $\frac{1}{2}$Cr–$\frac{1}{2}$Mo, 1Cr–$\frac{1}{2}$Mo, 1$\frac{1}{4}$Cr–$\frac{1}{2}$Mo–Si, 2$\frac{1}{4}$Cr–1Mo, 3Cr–1Mo, and 5Cr–$\frac{1}{2}$Mo. Longitudinal welds shall either be normalized, normalized and tempered, or subjected to proper subcritical PWHT for the alloy.

(11) Longitudinal seam fusion welded construction is not permitted for C–$\frac{1}{2}$Mo steel for operation in the creep range [see Notes (2) and (4)].

(12) The CSEF (creep strength enhanced ferritic) steels include Grades 91, 92, 911, 122, and 23.

(13) N+T = normalizing + tempering PWHT.

(14) WSRFs have been assigned for austenitic stainless (including 800H and 800HT) longitudinally welded pipe up to 1,500°F as follows:

Temperature, °F	Temperature, °C	Weld Strength Reduction Factor
1,250	677	0.73
1,300	704	0.68
1,350	732	0.64
1,400	760	0.59
1,450	788	0.55
1,500	816	0.5

(15) Certain heats of the austenitic stainless steels, particularly for those grades whose creep strength is enhanced by the precipitation of temper-resistant carbides and carbo-nitrides, can suffer from an embrittlement condition in the weld heat affected zone that can lead to premature failure of welded components operating at elevated temperatures. A solution annealing heat treatment of the weld area mitigates this susceptibility.

(16) Autogenous SS welded pipe (without weld filler metal) has been assigned a WSRF up to 1500°F of 1.00, provided that the product is solution annealed after welding and receives nondestructive electric examination, in accordance with the material specification.

Design pressure shall not exceed

$$P = \frac{2SE(t_m - A)}{D_o - 2y(t_m - A)} \qquad (4)^3$$

$$P = \frac{2SE(t_m - A)}{d - 2y(t_m - A) + 2t_m} \qquad (4A)^3$$

where the nomenclature used above is:

(A.1) t_m = minimum required wall thickness, in. (mm)

(A.1.1) If pipe is ordered by its nominal wall thickness, the manufacturing tolerance on wall thickness must be taken into account. After the minimum pipe wall thickness t_m is determined by eq. (3) or (3A), this minimum thickness shall be increased by an amount sufficient to provide the manufacturing tolerance allowed in the applicable pipe specification or required by the process. The next heavier commercial wall thickness shall then be selected from thickness schedules such as contained in ASME B36.10M or from manufacturers' schedules for other than standard thickness.

(A.1.2) To compensate for thinning in bends, refer to para. 102.4.5.

(A.1.3) For cast piping components, refer to para. 102.4.6.

(A.1.4) Where ends are subject to forming or machining for jointing, the wall thickness of the pipe, tube, or component after such forming or machining shall not be less than t_m minus the amount provided for removal by para. 104.1.2 (A.6.1).

(A.2) P = internal design pressure, psig [kPa (gage)]

NOTE: When computing the design pressure for a pipe of a definite minimum wall thickness by eq. (4) or (4A), the value of P obtained by these formulas may be rounded out to the next higher unit of 10. For cast iron pipe, see para. 104.1.2(B).

(A.3) D_0 = outside diameter of pipe, in. (mm). For design calculations, the outside diameter of pipe as given in tables of standards and specifications shall be used in obtaining the value of t_m. When calculating the allowable working pressure of pipe on hand or in stock, the actual measured outside diameter and actual measured minimum wall thickness at the thinner end of the pipe may be used to calculate this pressure.

(A.4) d = inside diameter of pipe, in. (mm). For design calculations, the inside diameter of pipe is the maximum possible value allowable under the purchase specification. When calculating the allowable working pressure of pipe on hand or in stock, the actual measured inside diameter and actual measured minimum wall thickness at the thinner end of the pipe may be used to calculate this pressure.

(A.5) SE or SF = maximum allowable stress in material due to internal pressure and joint efficiency (or casting quality factor) at the design temperature, psi (MPa). The value of SE or SF shall not exceed that given in Appendix A, for the respective material and design temperature. These values include the weld joint efficiency, E, or the casting factor, F.

(A.6) A = additional thickness, in. (mm)

(A.6.1) To compensate for material removed in threading, grooving, etc., required to make a mechanical joint, refer to para. 102.4.2.

(A.6.2) To provide for mechanical strength of the pipe, refer to para. 102.4.4 (not intended to provide for extreme conditions of misapplied external loads or for mechanical abuse).

(A.6.3) To provide for corrosion and/or erosion, refer to para. 102.4.1.

(A.7) y = coefficient having values as given in Table 104.1.2(A)

(B) Thickness of gray and ductile iron fittings conveying liquids may be determined from ANSI/AWWA C110/A21.10 or ANSI/AWWA C153/A21.53. The thickness of ductile iron pipe may be determined by ANSI/AWWA C115/A21.15 or ANSI/AWWA C150/A21.50. These thicknesses include allowances for foundry tolerances and water hammer.

(C) While the thickness determined from eq. (3) or (3A) is theoretically ample for both bursting pressure and material removed in threading, the following minimum requirements are mandatory to furnish added mechanical strength:

(C.1) Where steel pipe is threaded and used for steam service at pressure above 250 psi (1 750 kPa) or for water service above 100 psi (700 kPa) with water temperature above 220°F (105°C), the pipe shall be seamless having the minimum ultimate tensile strength of 48,000 psi (330 MPa) and a weight at least equal to Schedule 80 of ASME B36.10M.

(C.2) Where threaded brass or copper pipe is used for the services described in (C.1) above, it shall comply with pressure and temperature classifications permitted for these materials by other paragraphs of this Code and shall have a wall thickness at least equal to that specified above for steel pipe of corresponding size.

(C.3) Plain end nonferrous pipe or tube shall have minimum wall thicknesses as follows:

Table 104.1.2(A) Values of *y*

Temperature, °F	900 and Below	950	1,000	1,050	1,100	1,150	1,200	1,250 and Above
Temperature, °C	482 and Below	510	538	566	593	621	649	677 and Above
Ferritic steels	0.4	0.5	0.7	0.7	0.7	0.7	0.7	0.7
Austenitic steels	0.4	0.4	0.4	0.4	0.5	0.7	0.7	0.7
Nickel alloys UNS Nos. N06617, N08800, N08810, N08825	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.7

GENERAL NOTES:

(a) The value of y may be interpolated between the 50°F (27.8°C) values shown in the Table. For cast iron and nonferrous materials, y equals 0.

(b) For pipe with a D_o/t_m ratio less than 6, the value of y for ferritic and austenitic steels designed for temperatures of 900°F (480°C) and below shall be taken as:

$$y = \frac{d}{d + D_o} \tag{5}$$

(C.3.1) For nominal sizes smaller than NPS $^3\!/_4$, the thickness shall not be less than that specified for Type K of ASTM B 88.

(C.3.2) For nominal sizes NPS $^3\!/_4$ and larger, the wall thickness shall not be less than 0.049 in. (1.25 mm). The wall thickness shall be further increased, as required, in accordance with para. 102.4.

104.1.3 Straight Pipe Under External Pressure. For determining wall thickness and stiffening requirements for straight pipe under external pressure, the procedures outlined in UG-28, UG-29, and UG-30 of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code shall be followed.

(A08) **104.1.4 Longitudinal-Welded or Spiral-Welded Pipe Operating in the Creep Range.** The minimum thickness of pipe wall required for design pressures and for temperature not exceeding that for the various materials listed in the Allowable Stress Tables shall not be less than that determined by eq. (14) or (14A) as follows:

$$t_m = \frac{PD_o}{2(SEW + Py)} + A \tag{14}$$

$$t_m = \frac{Pd + SEW + 2yPA}{2(SEW + Py - P)} \tag{14A}$$

Design pressure shall not exceed

$$P = \frac{2SEW(t_m - A)}{D_o - 2y(t_m - A)} \tag{15}$$

$$P = \frac{2SEW(t_m - A)}{d - 2y(t_m - A) + 2t_m} \tag{15A}$$

where the nomenclature used above is given in para. 104.1.2 and

E = weld joint efficiency factor (as given in Table 102.4.3 and referenced in Appendix A tables)

SE = maximum allowable stress in material due to internal pressure and joint efficiency at the design temperature, psi (MPa). The value of *SE* shall not exceed that given in Appendix A, for the respective material and design temperature. These values include the weld joint efficiency factor, *E*.

W = weld strength reduction factor (see para. 102.4.7)

Also see requirements in para. 123.4 and Table 102.4.3.

104.2 Curved Segments of Pipe

104.2.1 Pipe Bends. Pipe bends shall be subject to the following limitations:

(A) The minimum wall thickness shall meet the requirements of para. 102.4.5 and the fabrication requirements of para. 129.

(B) Limits on flattening and buckling at bends may be specified by design, depending upon the service, the material, and the stress level involved. Where limits on flattening and buckling are not specified by design, the requirements of para. 129.1 shall be met.

104.2.2 Elbows. Elbows manufactured in accordance with the standards listed in Table 126.1 are suitable for use at the pressure–temperature ratings specified by such standards, subject to the requirements of para. 106.

104.3 Intersections

104.3.1 Branch Connections

(A) This paragraph gives rules governing the design of branch connections to sustain internal and external

pressure in cases where the axes of the branch and the run intersect, and the angle between the axes of the branch and of the run is between 45 deg and 90 deg, inclusive.

Branch connections in which the smaller angle between the axes of the branch and the run is less than 45 deg or branch connections where the axes of the branch and the run do not intersect impose special design and fabrication problems. The rules given herein may be used as a guide, but sufficient additional strength must be provided to assure safe service. Such branch connections shall be designed to meet the requirement of para. 104.7.

(B) Branch connections in piping may be made from materials listed in Appendix A by the use of the following:

(B.1) fittings, such as tees, laterals, and crosses made in accordance with the applicable standards listed in Table 126.1 where the attachment of the branch pipe to the fitting is by butt welding, socket welding, brazing, soldering, threading, or by a flanged connection.

(B.2) weld outlet fittings, such as cast or forged nozzles, couplings and adaptors, or similar items where the attachment of the branch pipe to the fitting is by butt welding, socket welding, threading, or by a flanged connection. Such weld outlet fittings are attached to the run by welding similar to that shown in Fig. 127.4.8(E). Couplings are restricted to a maximum of NPS 3.

(B.3) extruded outlets at right angles to the run pipe, in accordance with (G) below, where the attachment of the branch pipe is by butt welding.

(B.4) piping directly attached to the run pipe by welding in accordance with para. 127.4.8 or by socket welding or threading as stipulated below:

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(B.4.1) socket welded right angle branch connections may be made by attaching the branch pipe directly to the run pipe provided.

(B.4.1.1) the nominal size of the branch does not exceed NPS 2 or one-fourth of the nominal size of the run, whichever is smaller.

(B.4.1.2) the depth of the socket measured at its minimum depth in the run pipe is at least equal to that shown in ASME B16.11. If the run pipe wall does not have sufficient thickness to provide the proper depth of socket, an alternate type of construction shall be used.

(B.4.1.3) the clearance between the bottom of the socket and the end of the inserted branch pipe is in accordance with Fig. 127.4.4(C).

(B.4.1.4) the size of the fillet weld is not less than 1.09 times the nominal wall thickness of the branch pipe.

(B.4.2) threaded right angle branch connections may be made by attaching the branch pipe directly to the run provided

(B.4.2.1) the nominal size of the branch does not exceed NPS 2 or one-fourth of the nominal size of the run, whichever is smaller.

(B.4.2.2) the minimum thread engagement is: 6 full threads for NPS $\frac{1}{2}$ and NPS $\frac{3}{4}$ branches; 7 for NPS 1, NPS $1\frac{1}{4}$, and NPS $1\frac{1}{2}$ branches; and 8 for NPS 2 branches. If the run pipe wall does not have sufficient thickness to provide the proper depth for thread engagement, an alternative type of construction shall be used.

(C) Branch Connections Not Requiring Reinforcement. A pipe having a branch connection is weakened by the opening that must be made in it. Unless the wall thickness of the branch and/or run pipe is sufficiently in excess of that required to sustain the pressure, it is necessary to provide additional material in order to meet the reinforcement requirements of (D) and (E) below. However, there are certain branch connections for which supporting calculations are not required. These are as follows:

(C.1) branch connections made by the use of a fitting (tee, lateral, cross, or branch weld-on fitting), manufactured in accordance with a standard listed in Table 126.1, and used within the limits of pressure–temperature ratings specified in that standard.

(C.2) branch connections made by welding a coupling or half coupling directly to the run pipe in accordance with Fig. 127.4.8(E), provided the nominal diameter of the branch does not exceed NPS 2 or one-fourth the nominal diameter of the run, whichever is less. The minimum wall thickness of the coupling anywhere in the reinforcement zone (if threads are in the zone, wall thickness is measured from the root of the thread to the minimum O.D.) shall not be less than that of the unthreaded branch pipe. In no case shall the thickness of the coupling be less than extra heavy or Class 3000 rating.

Small branch connections NPS 2 or smaller as shown in Fig. 127.4.8(F) may be used, provided t_w is not less than the thickness of schedule 160 pipe of the branch size.

(C.3) integrally reinforced fittings welded directly to the run pipe when the reinforcements provided by the fitting and the deposited weld metal meets the requirements of (D) below.

(C.4) integrally reinforced extruded outlets in the run pipe. The reinforcement requirements shall be in accordance with (G) below.

(D) Branch Connections Subject to Internal Pressure Requiring Reinforcement

(D.1) Reinforcement is required when it is not provided inherently in the components of the branch connection. This paragraph gives rules covering the design of branch connections to sustain internal pressure in cases where the angle between the axes of the branch and of the run is between 45 deg and 90 deg. Subparagraph (E) below gives rules governing the design of connections to sustain external pressure.

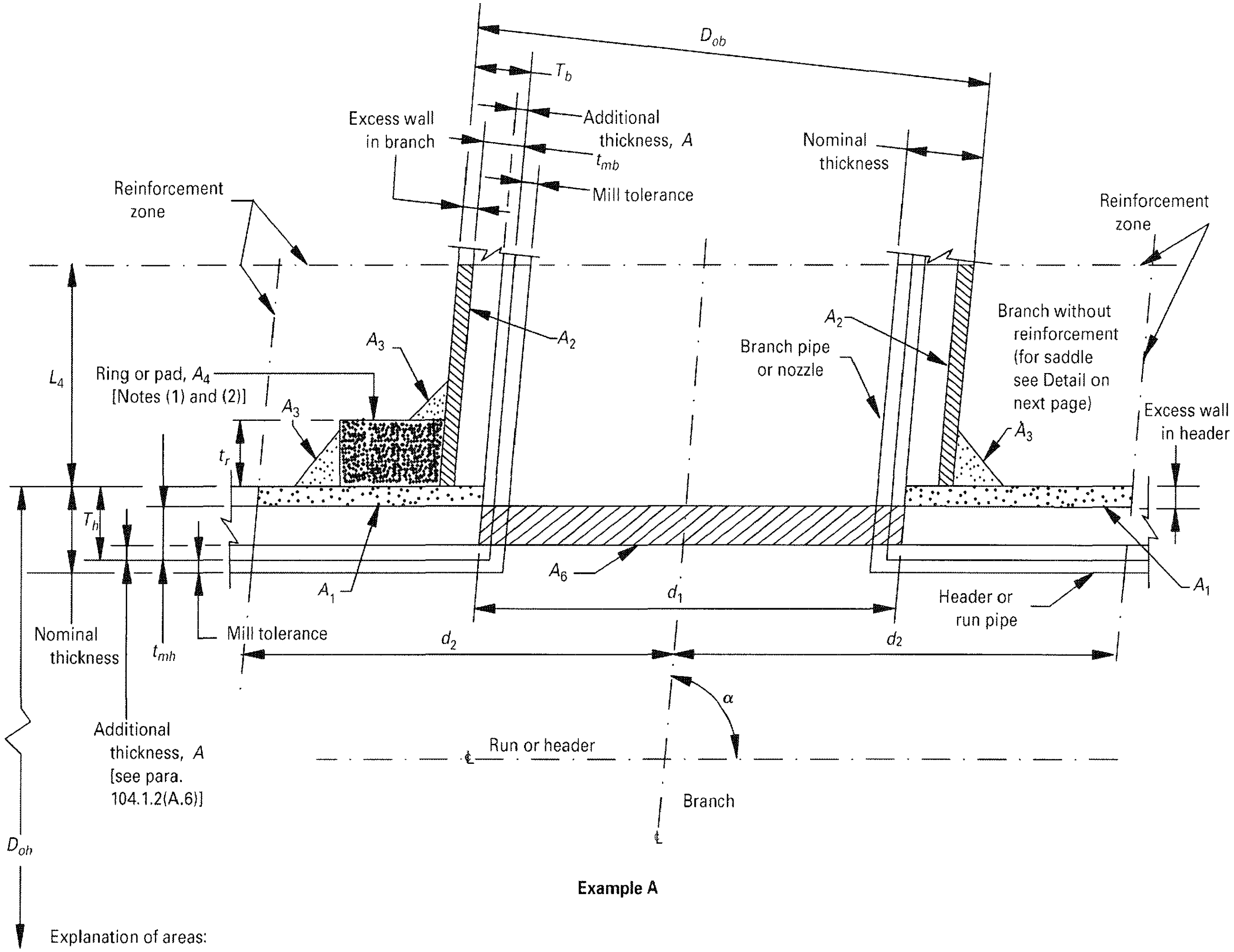
(D.2) Figure 104.3.1(D) illustrates the notations used in the pressure–temperature design conditions of branch connections. These notations are as follows: **(07)** **(A08)**

b = subscript referring to branch
D_{ob} = outside diameter of branch, in. (mm)
D_{oh} = outside diameter of header, in. (mm)
d_1 = inside centerline longitudinal dimension of the finished branch opening in the run of the pipe, in. (mm)
$= [D_{ob} - 2(T_b - A)]/\sin \alpha$
d_2 = "half width" of reinforcing zone, in. (mm)
= the greater of d_1 or $(T_b - A) + (T_h - A) + d_1/2$ but in no case more than D_{oh}, in. (mm)
h = subscript referring to run or header
L_4 = altitude of reinforcement zone outside of run, in. (mm)
$= 2.5(T_b - A) + t_r$ or $2.5(T_h - A)$, whichever is smaller
t_r = thickness of attached reinforcing pad, in Example A, in. (mm); or height of the largest 60 deg right triangle supported by the run and branch outside diameter projected surfaces and lying completely within the area of integral reinforcement, in Example B, in. (mm)
T_b, T_h = actual (by measurement), or minimum wall thickness of the branch or header pipe, in. (mm), permissible under purchase specification
t_{mb}, t_{mh} = required minimum wall thickness, in. (mm), of the branch or header pipe as determined by use of eq. (3) or (3A) in para. 104.1.2(A)
α = angle between axes of branch and run, deg

(D.2.1) If the run pipe contains a longitudinal seam which is not intersected by the branch, the stress value of seamless pipe of comparable grade may be

(07)

Fig. 104.3.1(D) Reinforcement of Branch Connections



Example A

Explanation of areas:

- ⁙ Area A_1 — available reinforcement area (excess wall) in header
- ▧ Area A_2 — available reinforcement area (excess wall) in branch
- ⁘ Area A_3 — available reinforcement area fillet weld metal
- ▩ Area A_4 — metal in ring, pad, or integral reinforcement
- ▥ Area A_5 — metal in saddle parallel to run (see Detail)
- ▨ Area A_6 — pressure design area (expected at the end of service life)

(F) Branch Connections Subject to External Forces and Moments. The requirements of the preceding paragraphs are intended to assure safe performance of a branch connection subjected only to pressure. However, when external forces and moments are applied to a branch connection by thermal expansion and contraction, by dead weight of piping, valves, and fittings, covering and contents, or by earth settlement, the branch connection shall be analyzed considering the stress intensification factors as specified in Appendix D. Use of ribs, gussets, and clamps designed in accordance with para. 104.3.4 is permissible to stiffen the branch connection, but their areas cannot be counted as contributing to the required reinforcement area of the branch connection.

(G) Extruded Outlets Integrally Reinforced

(G.1) The following definitions, modifications, notations, and requirements are specifically applicable to extruded outlets. The designer shall make proper wall thickness allowances in order that the required minimum reinforcement is assured over the design life of the system.

(G.2) Definition. An extruded outlet header is defined as a header in which the extruded lip at the outlet has an altitude above the surface of the run which is equal to or greater than the radius of curvature of the external contoured portion of the outlet; i.e., $h_o \geq r_o$. See nomenclature and Fig. 104.3.1(G).

(G.3) These rules apply only to cases where the axis of the outlet intersects and is perpendicular to the axis of the run. These rules do not apply to any nozzle in which additional nonintegral material is applied in the form of rings, pads, or saddles.

(A08) *(G.4)* The notation used herein is illustrated in Fig. 104.3.1(G). All dimensions are in inches (millimeters).

D_{ob} = outside diameter of branch pipe
D_{oh} = outside diameter of run
d_b = corroded internal diameter of branch pipe
d_c = corroded internal diameter of extruded outlet measured at the level of the outside surface of the run
d_r = corroded internal diameter of run
h_o = height of the extruded lip. This must be equal to or greater than r_o, except as shown in (G.4.2) below.
L_8 = altitude of reinforcement zone
= $0.7\sqrt{D_{ob}T_o}$
T_o = corroded finished thickness of extruded outlet measured at a height equal to r_o above the outside surface of the run
$t_b - A$ = actual thickness of branch wall, not including corrosion allowance
$t_h - A$ = actual thickness of run wall, not including the corrosion allowance
$t_{mb} - A$ = required thickness of branch pipe according to wall thickness eq. (3) or (3A) in para. 104.1.2(A), but not including any thickness for corrosion
$t_{mh} - A$ = required thickness of the run according to eq. (3) or (3A) in para. 104.1.2(A), but not including any allowance for corrosion
r_1 = half width of reinforcement zone (equal to d_c)
r_o = radius of curvature of external contoured portion of outlet measured in the plane containing the axes of the run and branch. This is subject to the following limitations:

(G.4.1) Minimum Radius. This dimension shall not be less than $0.05D_{ob}$ except that on branch diameters larger than NPS 30, it need not exceed 1.50 in. (38 mm).

(G.4.2) Maximum Radius. For outlet pipe sizes 6 in. (150 mm) nominal and larger, this dimension shall not exceed $0.10D_{ob}$ + 0.50 in. ($0.10D_{ob}$ + 12.7 mm). For outlet pipe sizes less than NPS 6, this dimension shall be not greater than 1.25 in. (32 mm).

(G.4.3) When the external contour contains more than one radius, the radius of any arc sector of approximately 45 deg shall meet the requirements of (G.4.1) and (G.4.2) above. When the external contour has a continuously varying radius, the radius of curvature at every point on the contour shall meet the requirements of (G.4.1) and (G.4.2) above.

(G.4.4) Machining other than grinding for weld cleanup shall not be employed in order to meet the above requirements.

(G.5) Required Area. The required area is defined as **(A08)**

$$A_7 = K\,(t_{mh} - A)\,d_c$$

where K shall be taken as follows:

For D_{ob}/D_{oh} greater than 0.60,

$$K = 1.00$$

For D_{ob}/D_{oh} greater than 0.15 and not exceeding 0.60,

$$K = 0.6 + \tfrac{2}{3}\,D_{ob}/D_{oh}$$

For D_{ob}/D_{oh} equal to or less than 0.15,

$$K = 0.70$$

The design must meet criteria that the reinforcement area defined in (G.6) below is not less than the required area.

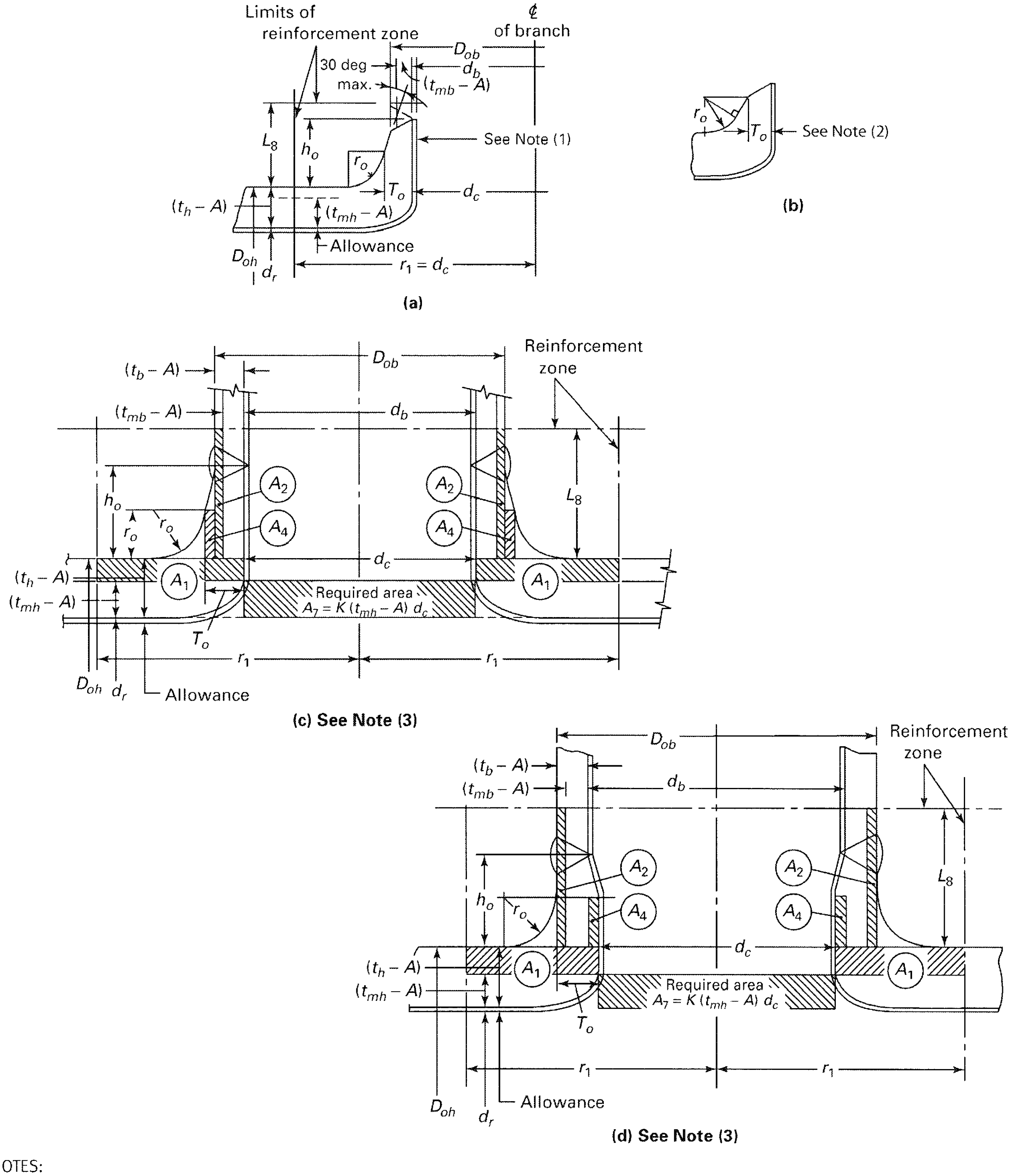
(G.6) Reinforcement Area. The reinforcement area shall be the sum of areas

$$A_1 + A_2 + A_4$$

as defined below.

(A08)

Fig. 104.3.1(G) Reinforced Extruded Outlets



(a)

(b)

(c) See Note (3)

(d) See Note (3)

NOTES:

(1) Taper bore inside diameter (if required) to match branch pipe 1:3 maximum taper.

(2) Sketch to show method of establishing T_o when the taper encroaches on the crotch radius.

(3) Sketch is drawn for condition where k = 1.00.

where

D = nominal pipe size (NPS), in. (mm)

E_c = modulus of elasticity at room temperature, psi (kPa)

L = developed length of pipe (total length of pipe taken along the piping longitudinal axes), ft (m)

S_A = allowable displacement stress range determined in accordance with para. 102.3.2(B), eq. (1A), psi (kPa)

U = anchor distance (length of straight line between the anchors), ft (m)

Y = resultant displacement between the anchors to be absorbed by the piping system, in. (mm)

WARNING: No general proof can be offered that this equation will yield accurate or consistently conservative results. It was developed for ferrous materials and is not applicable to systems used under severe cyclic conditions. It should be used with caution in configurations such as unequal leg U-bends ($L/U > 2.5$), or near straight "saw-tooth" runs, or for large diameter thin-wall pipe, or where extraneous displacements (not in the direction connecting anchor points) constitute a large part of the total displacement, or where piping operates in the creep range. There is no assurance that anchor reactions will be acceptably low, even when a piping system meets the above requirements.

(B) All systems not meeting the above criteria, or where reasonable doubt exists as to adequate flexibility between the anchors, shall be analyzed by simplified, approximate, or comprehensive methods of analysis that are appropriate for the specific case. The results of such analysis shall be evaluated using para. 104.8.3, eq. (13).

(C) Approximate or simplified methods may be applied only if they are used for the range of configurations for which their adequate accuracy has been demonstrated.

(D) Acceptable comprehensive methods of analysis include: analytical, model tests, and chart methods which provide an evaluation of the forces, moments and stresses caused by bending and torsion from the simultaneous consideration of terminal and intermediate restraints to thermal expansion of the entire piping system under consideration, and including all external movements transmitted to the piping by its terminal and intermediate attachments. Correction factors shall be applied for the stress intensification of curved pipe and branch connections, as provided by the details of these rules, and may be applied for the increased flexibility of such component parts.

119.7.3 Basic Assumptions and Requirements. In calculating the flexibility or displacement stresses of a piping system between anchor points, the system between anchor points shall be treated as a whole. The significance of all parts of the line and of all restraints, such as supports or guides, including intermediate restraints introduced for the purpose of reducing moments and forces on equipment or small branch lines, shall be considered.

Flexibility calculations shall take into account stress intensifying conditions found in components and joints. Credit may be taken when extra flexibility exists in such components. In the absence of more directly applicable data, the flexibility factors and stress-intensification factors shown in Appendix D may be used.[4]

Dimensional properties of pipe and fittings used in flexibility calculations shall be based on nominal dimensions.

The total reference displacement range resulting from using the coefficient of thermal expansion determined in accordance with para. 119.6.1 shall be used, whether or not the piping is cold sprung. Not only the expansion of the line itself, but also linear and angular movements of the equipment to which it is attached, shall be considered.

Where simplifying assumptions are used in calculations or model tests, the likelihood of attendant underestimates of forces, moments, and stresses, including the effects of stress intensification, shall be evaluated.

119.8 Movements

Movements caused by thermal expansion and loadings shall be determined for consideration of obstructions and design of proper supports.

119.9 Cold Spring

The beneficial effect of judicious cold springing in assisting a system to attain its most favorable position sooner is recognized. Inasmuch as the life of a system under cyclic conditions depends on the stress range rather than the stress level at any one time, no credit for cold spring is allowed with regard to stresses. In calculating end thrusts and moments acting on equipment, the actual reactions at any one time, rather than their range, are significant. Credit for cold springing is accordingly allowed in the calculation of thrusts and moments, provided an effective method of obtaining the designed cold spring is specified and used.

119.10 Reactions

119.10.1 Computing Hot and Cold Reactions. In a piping system with no cold spring or an equal percentage of cold springing in all directions, the reactions (forces and moments) of R_h and R_c, in the hot and cold conditions, respectively, shall be obtained from the reaction, R, derived from the flexibility calculations based **(A08)**

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[4] The stress-intensification factors in Appendix D have been developed from fatigue tests of representative commercially available, matching product forms and assemblies manufactured from ductile ferrous materials. The allowable stress range is based on tests of carbon and stainless steels. Caution should be exercised when applying Figs. (1) and (13) for the allowable stress range for certain nonferrous materials (e.g., copper and aluminum alloys) for other than low cycle applications.

on the modulus of elasticity at room temperature, E_c, using eqs. (9) and (10).

$$R_h = \left(1 - {}^2/_3C\right)\left(\frac{E_h}{E_c} R\right) \tag{9}$$

$$R_c = -CR, \text{ or}$$

$$= -\left[1 - \frac{(S_h)}{(S_E)} \cdot \frac{(E_c)}{(E_h)}\right] R \tag{10}$$

whichever is greater, and with the further condition that

$$\frac{(S_h)}{(S_E)} \cdot \frac{(E_c)}{(E_h)} < 1$$

where

C = cold spring factor varying from zero for no cold spring to 1.00 for 100% cold spring

E_c = modulus of elasticity in the cold condition, psi (MPa)

E_h = modulus of elasticity in the hot condition, psi (MPa)

R = maximum reaction for full expansion range based on E_c which assumes the most severe condition (100% cold spring, whether such is used or not), lb and in.-lb (N and mm·N)

R_c, R_h = maximum reactions estimated to occur in the cold and hot conditions, respectively, lb and in.-lb (N and mm·N)

S_E = computed thermal expansion stress range, psi (MPa)

S_h = basic material allowable stress at maximum (hot) temperature, without the 20 ksi limitation as noted in para. 102.3.2(C)

If a piping system is designed with different percentages of cold spring in various directions, eqs. (9) and (10) are not applicable. In this case, the piping system shall be analyzed by a comprehensive method. The calculated hot reactions shall be based on theoretical cold springs in all directions not greater than two-thirds of the cold springs as specified or measured.

119.10.2 Reaction Limits. The reactions computed shall not exceed limits which the attached equipment can sustain. Equipment allowable reaction limits (forces and moments) on piping connections are normally established by the equipment manufacturer.

120 LOADS ON PIPE SUPPORTING ELEMENTS

120.1 General

(A) The broad terms "supporting elements" or "supports" as used herein shall encompass the entire range of the various methods of carrying the weight of pipe lines, insulation, and the fluid carried. It, therefore, includes "hangers" that are generally considered as those elements which carry the weight from above, with the supporting members being mainly in tension. Likewise, it includes "supports" which on occasion are delineated as those that carry the weight from below, with the supporting members being mainly in compression. In many cases a supporting element may be a combination of both of these.

(B) In addition to the weight effects of piping components, consideration shall be given in the design of pipe supports to other load effects introduced by service pressure, wind, earthquake, etc., as defined in para. 101. Hangers and supporting elements shall be fabricated and assembled to permit the free movement of piping caused by thermal expansion and contraction. The design of elements for supporting or restraining piping systems, or components thereof, shall be based on all the concurrently acting loads transmitted into the supporting elements.

(C) Where the resonance with imposed vibration and/or shock occurs during operation, suitable dampeners, restraints, anchors, etc., shall be added to remove these effects.

120.2 Supports, Anchors, and Guides

120.2.1 Rigid-Type Supports

(A) The required strength of all supporting elements shall be based on the loadings as given in para. 120.1, including the weight of the fluid transported or the fluid used for testing, whichever is heavier. The allowable stress in supporting equipment shall be as specified in para. 121.2.

(B) Exceptions may be made in the case of supporting elements for large size gas or air piping, exhaust steam, relief or safety valve relief piping, but only under the conditions where the possibility of the line becoming full of water or other liquid is very remote.

120.2.2 Variable and Constant Supports. Load calculations for variable and constant supports, such as springs or counterweights, shall be based on the design operating conditions of the piping. They shall not include the weight of the hydrostatic test fluid. However, the support shall be capable of carrying the total load under test conditions, unless additional support is provided during the test period.

120.2.3 Anchors or Guides. Where anchors or guides are provided to restrain, direct, or absorb piping movements, their design shall take into account the forces and moments at these elements caused by internal pressure and thermal expansion.

120.2.4 Supplementary Steel. Where it is necessary to frame structural members between existing steel members, such supplementary steel shall be designed in accordance with American Institute of Steel Construction specifications, or similar recognized structural design standards. Increases of allowable stress values

(B) The value of P to be used in the formulas in para. 104 shall be not less than the maximum allowable working pressure of the boiler except as provided by para. 122.1.1(B).

(C) Valve requirements for water level indicators or water columns, special gage glass and gage cock requirements, minimum line sizes, and special piping configurations required specifically for cleaning, access, or reliability shall be in accordance with PG-60 of Section I of the ASME Boiler and Pressure Vessel Code.

122.1.7 Valves and Fittings. The minimum pressure and temperature rating for all valves and fittings in steam, feedwater, blowoff, and miscellaneous piping shall be equal to the pressure and temperature specified for the connected piping on the side that has the higher pressure, except that in no case shall the pressure be less than 100 psig [690 kPa (gage)], and for pressures not exceeding 100 psig [690 kPa (gage)] in feedwater and blowoff service, the valves and fittings shall be equal at least to the requirements of the ASME standards for Class 125 cast iron or bronze, or Class 150 steel or bronze.

(A) Steam Stop Valves. Each boiler discharge outlet, except safety valve or safety relief valve connections, or reheater inlet and outlet connections, shall be fitted with a stop valve located at an accessible point in the steam-delivery line and as near to the boiler nozzle as is convenient and practicable.

(A.1) Boiler stop valves shall provide bidirectional shutoff at design conditions. The valve or valves shall meet the requirements of para. 107. Valves with resilient (nonmetallic) seats shall not be used where the boiler maximum allowable working pressure exceeds 150 psig (1 035 kPa) or where the system design temperature exceeds 366°F (186°C). Valves of the outside screw and yoke, rising stem style are preferred. Valves other than those of the outside screw and yoke, rising stem style shall meet the following additional requirements.

(A.1.A) Each valve shall be equipped with a position indicator to visually indicate from a distance whether the valve is open or closed.

(A.1.B) Quarter turn valves shall be equipped with a slow operating mechanism to minimize dynamic loadings on the boiler and attached piping. Either a quick-opening manual quarter-turn valve or an automatic solenoid valve may be used on miniature boilers constructed in accordance with the rules contained in the ASME Boiler and Pressure Vessel Code, Section I, Parts PMB and PEB. Manual quarter-turn valves shall be provided with a handle or other position indicator to indicate from a distance whether the valve is open or closed.

(A.2) In the case of a single boiler and prime mover installation, the stop valve required herein may be omitted provided the prime mover throttle valve is equipped with an indicator to show whether it is opened or closed, and it is designed to withstand the required boiler hydrostatic test.

(A.3) When two or more boilers are connected to a common header, or when a single boiler is connected to a header having another steam source, the connection from each boiler having a manhole opening shall be fitted with two stop valves having an ample free-blow drain between them. The preferred arrangement consists of one stop-check valve (located closest to the boiler) and one valve of the style and design described in (A.1) above. Alternatively, both valves may be of the style and design described in (A.1) above.

When a second stop valve is required, it shall have a pressure rating at least equal to that required for the expected steam pressure and temperature at the valve, or a pressure rating at least equal to 85% of the lowest set pressure of any safety valve on the boiler drum at the expected temperature of the steam at the valve, whichever is greater.

(A.4) All valves and fittings on steam lines shall have a pressure rating of at least 100 psig [690 kPa (gage)] in accordance with the applicable ASME standard.

(B) Feedwater Valves

(B.1) The feedwater piping for all boilers, except for high temperature water boilers complying with the requirements of (B.8) below, and for forced flow steam generators with no fixed steam and water line complying with the requirements of (B.9) below, shall be provided with a check valve and a stop valve or cock between the check valve and the boiler. The stop valve or cock shall comply with the requirements of (C.5) below.

(B.2) The relative locations of the check and stop (or cock) valves, as required in (B.1) above, may be reversed on a single boiler-turbine unit installation.

(B.3) If a boiler is equipped with a duplicate feed arrangement, each such arrangement shall be equipped as required by these rules.

(B.4) When the supply line to a boiler is divided into branch feed connections and all such connections are equipped with stop and check valves, the stop and check valves in the common source may be omitted.

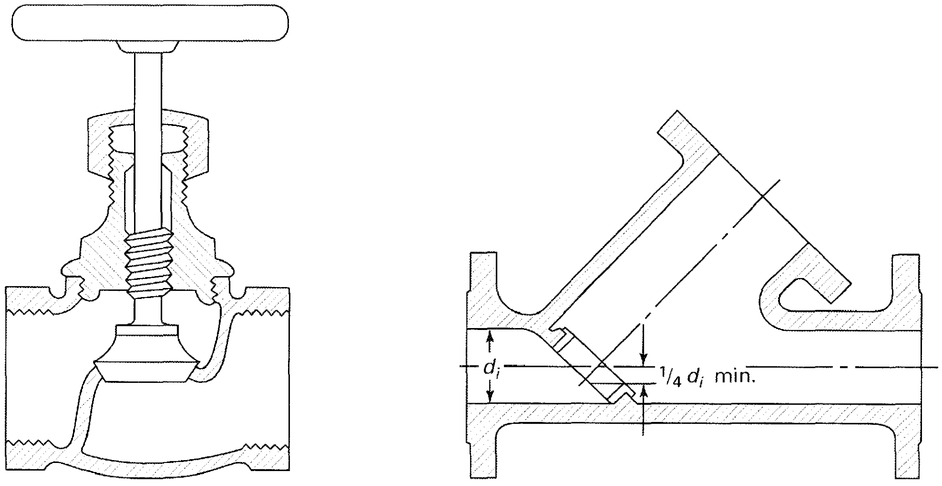
(B.5) When two or more boilers are fed from a common source, there shall also be a globe or regulating valve in the branch to each boiler located between the check valve and the source of supply. A typical arrangement is shown in Fig. 100.1.2(B).

(B.6) A combination stop and check valve in which there is only one seat and disk, and in which a valve stem is provided to close the valve, shall be considered only as a stop valve, and a check valve shall be installed as otherwise provided.

(B.7) Where an economizer or other feedwater heating device is connected directly to the boiler without intervening valves, the feed valves and check valves

(A08)

Fig. 122.1.7(C) Typical Globe Valves



(a) (b)

required shall be placed on the inlet of the economizer or feedwater heating device.

(B.8) The recirculating return line for a high temperature water boiler shall be provided with the same stop valve, or valves, required by (B.1) and (B.3) above. The use of a check valve in the recirculating return line is optional. A check valve shall not be a substitute for a stop valve.

(B.9) The feedwater boiler external piping for a forced flow steam generator with no fixed steam and water line may terminate up to and including the stop valve(s) and omitting the check valve(s) provided that a check valve having a pressure rating no less than the boiler inlet design pressure is installed at the discharge of each boiler feed pump or elsewhere in the feedline between the feed pump and the stop valve(s).

(B.10) Wherever globe valves are used within BEP feedwater piping for either isolation or regulation, the inlet shall be under the disk of the valve.

(C) Blowoff Valves

(C.1) Ordinary globe valves as shown in Fig. 122.1.7(C) sketch (a), and other types of valves that have dams or pockets where sediment can collect, shall not be used on blowoff connections.

(C.2) Y-type globe valves as shown in Fig. 122.1.7(C) sketch (b) or angle valves may be used in vertical pipes, or they may be used in horizontal runs of piping provided they are so constructed or installed that the lowest edge of the opening through the seat is at least 25% of the inside diameter below the centerline of the valve.

(C.3) The blowoff valve or valves, the pipe between them, and the boiler connection shall be of the same size except that a larger pipe for the return of condensate may be used.

(C.4) For all boilers [except electric steam boilers having a normal water content not exceeding 100 gal (380 L), traction-purpose, and portable steam boilers; see (C.11) and (C.12) below] with allowable working pressure in excess of 100 psig [690 kPa (gage)], each bottom blowoff pipe shall have two slow-opening valves, or one quick-opening valve or cock, at the boiler nozzle followed by a slow-opening valve. All valves shall comply with the requirements of (C.5) and (C.6) below.

(C.5) When the value of P required by para. 122.1.4(A.1) does not exceed 250 psig [1 725 kPa (gage)], the valves or cocks shall be bronze, cast iron, ductile iron, or steel. The valves or cocks, if of cast iron, shall not exceed NPS $2\frac{1}{2}$ and shall meet the requirements of the applicable ASME standard for Class 250, as given in Table 126.1, and if of bronze, steel, or ductile iron construction, shall meet the requirements of the applicable standards as given in Table 126.1 or para. 124.6.

(C.6) When the value of P required by para. 122.1.4(A.1) is higher than 250 psig [1 725 kPa (gage)], the valves or cocks shall be of steel construction equal at least to the requirements of Class 300 of the applicable ASME standard listed in Table 126.1. The minimum pressure rating shall be equal to the value of P required by para. 122.1.4(A.1).

(C.7) If a blowoff cock is used, the plug shall be held in place by a guard or gland. The plug shall be distinctly marked in line with the passage.

(C.8) A slow-opening valve is a valve which requires at least five 360 deg turns of the operating mechanism to change from fully closed to fully opened.

(C.9) On a boiler having multiple blowoff pipes, a single master valve may be placed on the common blowoff pipe from the boiler, in which case only one valve

Chapter III
Materials

123 GENERAL REQUIREMENTS

Chapter III contains limitations and required qualifications for materials based on their inherent properties. Use of these materials in piping systems is also subject to requirements and limitations in other parts of this Code.

123.1 Materials and Specifications

123.1.1 Listed Materials. Material meeting the following requirements shall be considered listed and acceptable material:

(A) Materials for which allowable stress values are listed in Appendix A or which have been approved by the procedure established by (C) below.

(B) A material conforming to a specification for which allowable stresses are not listed in Appendix A is acceptable provided its use is not specifically prohibited by this Code Section and it satisfies one of the following requirements:

(B.1) It is referenced in a standard listed in Table 126.1. Such a material shall be used only within the scope of and in the product form covered by the referencing standard listed in Table 126.1.

(B.2) It is referenced in other parts of this Code Section and shall be used only within the scope of and in the product form permitted by the referencing text.

(C) Where it is desired to use materials which are not currently acceptable under the rules of this Code Section, written application shall be made to the Committee fully describing the proposed material and the contemplated use. Such material shall not be considered listed and not used as a listed material until it has been approved by the Committee and allowable stress values have been assigned. Details of information which should be included in such applications are given in Appendix VI. See para. 123.1.2.

(D) Materials conforming to ASME SA or SB specifications may be used interchangeably with material specified to the listed ASTM A or B specifications of the same number, except where the requirements of para. 123.2.2 apply.

(E) The tabulated stress values in Appendix A that are shown in italics are at temperatures in the range where creep and stress rupture strength govern the selection of stresses.

123.1.2 Unlisted Materials. Materials other than those meeting the requirements of para. 123.1.1 shall be considered unlisted materials. Such unlisted materials may only be used for nonboiler external piping provided they satisfy all of the following requirements:

(A) Unlisted materials are certified by the material manufacturer to satisfy the requirements of a specification listed in any Code Section of the ASME B31 Code for Pressure Piping, the ASME Boiler and Pressure Vessel Code, Section II, Part D, or to a published specification covering chemistry, physical and mechanical properties, method and process of manufacture, heat treatment, and quality control.

(B) The allowable stresses of the unlisted materials shall be determined in accordance with the rules of para. 102.3.1(C).

(C) Unlisted materials shall be qualified for service within a stated range of minimum and maximum temperatures based upon data associated with successful experience, tests, or analysis; or a combination thereof.

(D) The designer shall document the owner's acceptance for use of unlisted material.

(E) All other requirements of this Code are satisfied.

123.1.3 Unknown Materials. Materials of unknown specification shall not be used for pressure containing piping components.

123.1.5 Size or Thickness. Materials outside the limits of size or thickness given in the title or scope clause of any specification listed in Table 126.1 may be used if the material is in compliance with the other requirements of the specification, and no other similar limitation is given in the rules for construction.

123.1.6 Marking of Materials or Products. Materials or products marked as meeting the requirements for more than one grade, type, or alloy of a material specification or multiple specifications, are acceptable provided

(A) one of the markings includes the material specification, grade, class, and type or alloy of the material permitted by this Code and the material meets all the requirements of that specification

(B) the appropriate allowable stress for the specified grade, type, or alloy of a material specification from Appendix A is used

(C) all other requirements of this Code are satisfied for the material permitted

123.1.7 Materials Manufactured to Other Specification Editions. Materials may meet the requirements of material specification editions other than the editions listed in Appendix F provided

(A) the materials are the same specification, grade, type, class, or alloy, and heat-treated condition, as applicable.

(B) the material tensile and yield strengths shall be compared and any differences shall be evaluated. If the material has a lower strength than required by the edition of the specification in Appendix F, the effect of the reduction on the allowable stress and the design shall be reconciled.

123.2 Piping Components

123.2.1 General. Materials which do not comply with the rules of para. 123.1 may be used for flared, flareless, and compression type tubing fittings, provided that the requirements of para. 115 are met.

123.2.2 Boiler External Piping

(A) Materials for boiler external piping, as defined in para. 100.1.2(A), shall be specified in accordance with ASME SA, SB, or SFA specifications. Material produced under an ASTM specification may be used, provided that the requirements of the ASTM specification are identical or more stringent than the ASME specification for the Grade, Class, or Type produced. The material manufacturer or component manufacturer shall certify, with evidence acceptable to the Authorized Inspector, that the ASME specification requirements have been met. Materials produced to ASME or ASTM material specifications are not limited as to country of origin.

(B) Materials which are not fully identified shall comply with PG-10 of Section I of the ASME Boiler and Pressure Vessel Code.

(A08) *(C)* In addition to materials listed in Appendix A without Note (1), materials that are listed in Section I of the ASME Boiler and Pressure Vessel Code may be used in boiler external piping. When such Section I materials are used, the allowable stresses shall be those listed in Section II, Part D, Subpart 1, Tables 1A and 1B applicable to Section I. For these Section I materials, the applicable requirements in Table 1A, Table 1B, and Section I paras. PG-5 through PG-13, PW-5, PWT-5, PMB-5, and PEB-5 shall me met.

123.3 Pipe-Supporting Elements

Materials used for pipe-supporting elements shall be suitable for the service and shall comply with the requirements of para. 121.2(C), para. 121.7.2(C), para. 121.7.2(D), para. 123.1, or MSS SP-58. When utilizing MSS SP-58, the allowable stresses for unlisted materials shall be established in accordance with the rules of para. 102.3.1(C) of ASME B31.1 in lieu of para. 4.4 of MSS SP-58.

123.4 Longitudinal-Welded or Spiral-Welded Pipe With Filler Metal Added (A08)

(A) For the purposes of para. 104.1.1, the start of the creep range is the highest temperature where the non-italicized stress values end in Appendix A.

(B) All welds in longitudinal-welded or spiral-welded pipe operating in the creep range shall receive and pass a 100% volumetric examination (RT or UT) per the applicable material specification or in accordance with para. 136.4.5 or 136.4.6 and Table 136.4, or the joint efficiency factor (used as a multiplier to the weld strength reduction factor) from Table 102.4.7 shall be used.

124 LIMITATIONS ON MATERIALS

124.1 Temperature Limitations

124.1.1 Upper Temperature Limits. The materials listed in the Allowable Stress Tables A-1 through A-9, Appendix A, shall not be used at design temperatures above those for which stress values are given except as permitted by para. 122.6.2(G).

124.1.2 Lower Temperature Limits. The designer shall give consideration to the possibility of brittle fracture at low service temperature.

124.2 Steel

(A) Upon prolonged exposure to temperatures above 800°F (427°C), the carbide phase of plain carbon steel, plain nickel alloy steel, carbon-manganese alloy steel, manganese-vanadium alloy steel, and carbon-silicon steel may be converted to graphite.

(B) Upon prolonged exposure to temperatures above 875°F (470°C), the carbide phase of alloy steels, such as carbon-molybdenum, manganese-molybdenum-vanadium, manganese-chromium-vanadium, and chromium-vanadium, may be converted to graphite.

(C) Carbon or alloy steel having carbon content of more than 0.35% shall not be used in welded construction or be shaped by oxygen cutting process or other thermal cutting processes.

(D) Where low alloy 2¼% chromium steels are used at temperatures above 850°F, the carbon content of the base material and weld filler metal shall be 0.05% or higher.

124.4 Cast Gray Iron (A08)

The low ductility of cast gray iron may result in sudden failure if shock loading (pressure, temperature, or mechanical) should occur. Possible shock loadings and consequences of failure must be considered before specifying the use of such material. Cast iron components may be used within the nonshock pressure–temperature ratings established by the standards and specifications herein and in para. 105.2.1(B). Castings to ASME SA-278 and ASTM A 278 shall have maximum limits of 250 psig [1 725 kPa (gage)] and 450°F (230°C).

The following referenced paragraphs prohibit or restrict the use of gray cast iron for certain applications or to certain pressure–temperature ratings:

Pipe supports	121.7.2(C)
BEP blowoff	122.1.4(A.3)
BEP blowdown	122.1.4(B.3)
BEP valves and fittings	122.1.7
Blowoff valves	122.1.7(C.5) & (C.6)
Non-BEP blowoff	122.2(A.1)
Non-BEP blowdown	122.2(A.2)
Flammable or combustible liquids	122.7.2(A) & (B), 122.7.4
Flammable gases	122.8.1(B) & (C)
Toxic gases or liquids	122.8.2(B) & (D)

(A08) 124.5 Malleable Iron

Certain types of malleable iron have low ductility characteristics and may be subject to brittle fracture. Malleable iron may be used for design conditions not to exceed 350 psig [2 415 kPa (gage)] or 450°F (230°C).

The following referenced paragraphs prohibit or restrict the use of malleable iron for certain applications or to certain pressure–temperature ratings:

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Pipe supports	121.7.2(D)
BEP blowoff	122.1.4(A.3)
BEP blowdown	122.1.4(B.3)
Non-BEP blowoff	122.2(A.1)
Non-BEP blowdown	122.2(A.2)
Flammable or combustible liquids	122.7.2(A) & (B)
Flammable gases	122.8.1(B) & (C)
Toxic gases or liquids	122.8.2(B) & (D)

124.6 Ductile (Nodular) Iron

Ductile iron components complying with ANSI/AWWA C110/A21.10, C115/A21.15, C151/A21.51, or C153/A21.53 may be used for water and other nontoxic, nonflammable service, with pressure limits as specified in those standards and temperature limits as specified in para. 106(E). These components may not be used for boiler external piping.

Ductile (nodular) iron components conforming to ASME B16.42 may be used for services including boiler external piping under the following conditions:

(A) Components for boiler external piping shall be used only within the following limitations.

(A.1) Only ASME SA-395 material may be used.

(A.2) Design pressure shall not exceed 350 psig [2 415 kPa (gage)].

(A.3) Design temperature shall not exceed 450°F (230°C).

(B) Welding shall not be used, either in fabrication of the components or in their assembly as a part of a piping system.

(A08) *(C)* The following referenced paragraphs prohibit or restrict the use of ductile iron for certain applications or to certain pressure–temperature ratings:

BEP blowoff	122.1.4(A.3)
BEP blowdown	122.1.4(B.3)
BEP blowoff valves	122.1.7(C.5) & (C.6)
Non-BEP blowoff	122.2(A.1)
Non-BEP blowdown	122.2(A.2)
Flammable or combustible liquids	122.7.2(A) & (B)
Flammable gases	122.8.1(B) & (C)
Toxic gases or liquids	122.8.2(B) & (D)
Pipe supports	123.3

124.7 Nonferrous Metals

Nonferrous metals may be used in piping systems under the following conditions:

(A) The melting points of copper, copper alloys, aluminum, and aluminum alloys must be considered particularly where there is a fire hazard.

(B) The Designer shall consider the possibility of galvanic corrosion when combinations of dissimilar metals, such as copper, aluminum, and their alloys, are used in conjunction with each other or with steel or other metals in the presence of an electrolyte.

(C) Threaded Connections. A suitable thread compound shall be used in making up threaded joints in aluminum pipe to prevent seizing which might cause leakage and perhaps prevent disassembly. Pipe in the annealed temper should not be threaded.

124.8 Cladding and Lining Materials

Materials with cladding or lining may be used provided that

(a) the base material is an approved Code material. The allowable stress used shall be that of the base metal at the design temperature.

(b) the cladding or lining is a material that in the judgment of the user is suitable for the intended service, and the cladding/lining and its method of application do not detract from the serviceability of the base material.

(c) bending procedures are such that damaging or detrimental thinning of the cladding material is prevented.

(d) welding and the inspection of welds is in accordance with the provisions of Chapters V and VI of this Code.

(e) the thickness of the cladding is not credited for structural strength in the piping design.

124.9 Nonmetallic Pipe

This Code recognizes the existence of a wide variety of nonmetallic piping materials which may be used on corrosive (either internal or external) or other specialized applications. Extreme care must be taken in their selection as their design properties vary greatly and depend upon the material, type and grade. Particular consideration shall be given to the possibility of

(A) destruction where fire hazard is involved.

(B) decrease in tensile strength at slight increase in temperature.

(C) effects of toxicity. Another consideration is that of providing adequate support for the flexible pipe.

For nonmandatory rules for nonmetallic piping, see Appendix III of this Code.

124.10 Deterioration of Materials in Service

It is the responsibility of the engineer to select materials suitable for the intended application. Some guideline for selection of protective coatings for metallic piping are provided in Appendix IV.

125 MATERIALS APPLIED TO MISCELLANEOUS PARTS

125.1 Gaskets

Limitations on gasket materials are covered in para. 108.4.

125.2 Bolting

Limitations on bolting materials are covered in para. 108.5.

Chapter IV
Dimensional Requirements

126 MATERIAL SPECIFICATIONS AND STANDARDS FOR STANDARD AND NONSTANDARD PIPING COMPONENTS

126.1 Standard Piping Components

Dimensions of standard piping components shall comply with the standards and specifications listed in Table 126.1 in accordance with para. 100.

126.2 Nonstandard Piping Components

When nonstandard piping components are designed in accordance with para. 104, adherence to dimensional standards of ANSI and ASME is strongly recommended when practicable.

126.3 Referenced Documents

The documents listed in Table 126.1 may contain references to codes, standards, or specifications not listed in this Table. Such unlisted codes, standards, or specifications are to be used only in the context of the listed documents in which they appear.

Where documents listed in Table 126.1 contain design rules which are in conflict with this Code, the design rules of this Code shall govern.

The fabrication, assembly, examination, inspection, and testing requirements of Chapters V and VI apply to the construction of piping systems. These requirements are not applicable to piping components manufactured in accordance with the documents listed in Table 126.1 unless specifically so stated.

Table 126.1 Specifications and Standards (Cont'd)

ASTM Nonferrous Material Specifications

Castings

	B 26/B 26M	Aluminum-Alloy Sand Castings
	B 61	Steam or Valve Bronze Castings
	B 62	Composition Bronze or Ounce Metal Castings
	B 108	Aluminum-Alloy Permanent Mold Castings
	B 148	Aluminum-Bronze Sand Castings
	B 367	Titanium and Titanium Alloy Castings
	B 584	Copper Alloy Sand Castings for General Applications

Forgings

	B 247 & B 247M	Aluminum and Aluminum-Alloy Die, Hand, and Rolled Ring Forgings
	B 283	Copper and Copper-Alloy Die Forgings (Hot Pressed)
	B 381	Titanium and Titanium Alloy Forgings
(A08)	B 462	Forged or Rolled UNS N06030, N06022, N06035, N06200, N06059, N06686, N08020, N08024, N08026, N08367, N10276, N10665, N10675, N10629, N08031, N06045, N06025, and R20033 Alloy Pipe Flanges, Forged Fittings, and Valves and Parts for Corrosive High-Temperature Service
	B 564	Nickel Alloy Forgings

Seamless Pipe and Tube

	B 42	Seamless Copper Pipe, Standard Sizes
	B 43	Seamless Red Brass Pipe, Standard Sizes
	B 68 & B 68M	Seamless Copper Tube, Bright Annealed
	B 75	Seamless Copper Tube
	B 88 & B 88M	Seamless Copper Water Tube
	B 111 & B 111M	Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock
	B 161	Nickel Seamless Pipe and Tube
	B 163	Seamless Nickel and Nickel-Alloy Condenser and Heat-Exchanger Tubes
	B 165	Nickel-Copper Alloy (UNS N04400) Seamless Pipe and Tube
	B 167	Nickel-Chromium-Iron Alloy (UNS N06600, N06601, N06603, N06690, N06693, N06025, and N06645) and Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617) Seamless Pipe and Tube
	B 210 & B 210M	Aluminum Alloy Drawn Seamless Tubes
	B 234 & B 234M	Aluminum and Aluminum-Alloy Drawn Seamless Tubes for Condensers and Heat Exchangers
	B 241/B 241M	Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube
	B 251 & B 251M	General Requirements for Wrought Seamless Copper and Copper-Alloy Tube
	B 280	Seamless Copper Tube for Air Conditioning and Refrigeration Field Service
	B 302	Threadless Copper Pipe, Standard Sizes
	B 315	Seamless Copper Alloy Pipe and Tube
	B 407	Nickel-Iron-Chromium Alloy Seamless Pipe and Tube
	B 423	Nickel-Iron-Chromium-Molybdenum-Copper Alloy (UNS N08825 and N08821) Seamless Pipe and Tube
	B 466 / B 466M	Seamless Copper-Nickel Pipe and Tube
(07)	B 622	Seamless Nickel and Nickel-Cobalt Alloy Pipe and Tube
	B 677	UNS N08904, UNS N08925, and UNS N08926 Seamless Pipe and Tube
(A08)	B 690	Iron-Nickel-Chromium-Molybdenum Alloys (UNS N08366 and UNS N08367) Seamless Pipe and Tube
	B 729	Seamless UNS N08020, UNS N08026, and UNS N08024 Nickel-Alloy Pipe and Tube
	B 861	Titanium and Titanium Alloy Seamless Pipe

Seamless and Welded Pipe and Tube

	B 338	Seamless and Welded Titanium and Titanium Alloy Tubes for Condensers and Heat Exchangers
	B 444	Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) Plate, Sheet, and Strip

Welded Pipe and Tube

	B 464	Welded (UNS N08020, N08024, N08026 Alloy) Pipe
	B 467	Welded Copper-Nickel Pipe
	B 468	Welded (UNS N08020, N08024, N08026) Alloy Tubes
	B 546	Electric Fusion-Welded Ni-Cr-Co-Mo Alloy (UNS N06617), Ni-Fe-Cr-Si Alloys (UNS N08330 and UNS N08332), Ni-Cr-Fe-Al Alloy (UNS N06603), Ni-Cr-Fe Alloy (UNS N06025), and Ni-Cr-Fe-Si Alloy (UNS N06045) Pipe

Table 126.1 Specifications and Standards (Cont'd)

ASTM Nonferrous Material Specifications (Cont'd)

Welded Pipe and Tube (Cont'd)

	B 547	Aluminum and Aluminum-Alloy Formed and Arc-Welded Round Tube
(A08)	B 608	Welded Copper-Alloy Pipe
(07)	B 619	Welded Nickel and Nickel-Cobalt Alloy Pipe
(07)	B 626	Welded Nickel and Nickel-Cobalt Alloy Tube
	B 673	UNS N08904, UNS N08925, and UNS N08926 Welded Pipe
	B 674	UNS N08904, UNS N08925, and UNS N08926 Welded Tube
(A08)	B 675	UNS N08367 Welded Pipe
(A08)	B 676	UNS N08367 Welded Tube
	B 704	Welded UNS N06625 and N08825 Alloy Tubes
	B 705	Nickel-Alloy (UNS N06625 and N08825) Welded Pipe
(A08)	B 804	UNS N08367 and UNS N08926 Welded Pipe
	B 862	Titanium and Titanium Alloy Welded Pipe

Fittings

	B 361	Factory-Made Wrought Aluminum and Aluminum-Alloy Welding Fittings
	B 366	Factory-Made Wrought Nickel and Nickel Alloy Fittings

(A08) Plate, Sheet, and Strip

	B 168	Nickel-Chromium-Iron Alloys (UNS N06600, N06601, N06603, N06690, N06693, N06025, N06045) and Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617) Plate, Sheet, and Strip
	B 171	Copper-Alloy Plate and Sheet for Pressure Vessels, Condensers, and Heat Exchangers
	B 209/B 209M	Aluminum and Aluminum-Alloy Sheet and Plate
	B 265	Titanium and Titanium-Alloy Strip, Sheet, and Plate
	B 409	Nickel-Iron-Chromium Alloy Plate, Sheet, and Strip
	B 424	Ni-Fe-Cr-Mo-Cu Alloy (UNS N08825 and N08221) Plate, Sheet, and Strip
(07)	B 435	UNS N06002, UNS N06230, UNS N12160, and UNS R30556 Plate, Sheet, and Strip
	B 443	Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) Plate, Sheet, and Strip
	B 463	UNS N08020, UNS N08026, and UNS N08024 Alloy Plate, Sheet, and Strip
	B 625	UNS N08904, UNS N08925, UNS N08031, UNS N08932, UNS N08926, and UNS R20033 Plate, Sheet, and Strip
	B 688	Chromium-Nickel-Molybdenum-Iron (UNS N08366 and UNS N08367) Plate, Sheet, and Strip

Rods, Bars, and Shapes

	B 150 & B 150M	Aluminum Bronze Rod, Bar, and Shapes
	B 151/B 151M	Copper-Nickel-Zinc Alloy (Nickel Silver) and Copper-Nickel Rod and Bar
	B 166	Nickel-Chromium-Iron Alloys (UNS N06600, N06601, N06603, N06690, N06693, N06025, and N06045) and Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617) Rod, Bar, and Wire
	B 221 & B 221M	Aluminum and Aluminum Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes
	B 348	Titanium and Titanium Alloy Bars and Billets
	B 408	Nickel-Iron-Chromium Alloy Rod and Bar
	B 425	Ni-Fe-Cr-Mo-Cu Alloy (UNS N08825 and N08221) Rod and Bar
	B 446	Nickel-Chromium Molybdenum-Columbium Alloy (UNS N06625) Rod and Bar
	B 473	UNS N08020, UNS N08024, and UNS N08026 Nickel Alloy Bar and Wire
(07)	B 572	UNS N06002, UNS N06230, UNS N12160, and UNS R30556 Rod
	B 649	Ni-Fe-Cr-Mo-Cu Low-Carbon Alloy (N08904), Ni-Fe-Cr-Mo-Cu-N Low-Carbon Alloys (UNS N08925, UNS N08031, and UNS N08926), and Cr-Ni-Fe-N Low-Carbon Alloy (UNS R20033) Bar and Wire
(A08)	B 691	Iron-Nickel-Chromium-Molybdenum Alloys (UNS N08366 and UNS N08367) Rod, Bar, and Wire

Solder

	B 32	Solder Metal
	B 828	Standard Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings

API Specification

Seamless and Welded Pipe

5L	Line Pipe

American National Standard

Z223.1	National Fuel Gas Code (ANSI/NFPA 54)

Table 126.1 Specifications and Standards (Cont'd)

MSS Standard Practices

SP-6	Standard Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings
SP-9	Spot-Facing for Bronze, Iron & Steel Flanges
SP-25	Standard Marking System for Valves, Fittings, Flanges and Unions
SP-42 [Note (1)]	Class 150 Corrosion Resistant Gate, Globe, Angle and Check Valves With Flanged and Buttweld Ends
SP-43	Wrought Stainless Steel Butt-Welding Fittings
SP-45	Bypass & Drain Connection
SP-51	Class 150 LW Corrosion Resistant Cast Flanges and Flanged Fittings
SP-53	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components — Magnetic Particle Examination Method
SP-54	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components — Radiographic Examination Method
SP-55	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components — Visual Method for Evaluation of Surface Irregularities
SP-58	Pipe Hangers & Supports, Materials, Design, and Manufacture
SP-61	Hydrostatic Testing Steel Valves
SP-67 [Note (1)]	Butterfly Valves
SP-68	High Pressure Butterfly Valves with Offset Design
SP-69	Pipe Hangers & Supports — Selection and Application
SP-75	Specification for High Test Wrought Butt-Welding Fittings
SP-79	Socket Welding Reducer Inserts
SP-80	Bronze Gate, Globe, Angle & Check Valve
SP-83	Class 3000 Steel Pipe Unions, Socket Welding and Threaded
SP-89	Pipe Hangers and Supports — Fabrication and Installation Practices
SP-93	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components — Liquid Penetrant Examination Method
SP-94	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components — Ultrasonic Examination Method
SP-95	Swage(d) Nipples and Bull Plugs
SP-97	Integrally Reinforced Forged Branch Outlet Fittings — Socket Welding, Threaded and Buttwelding Ends
SP-105	Instrument Valves for Code Applications
(07) SP-106	Cast Copper Alloy Flanges and Flanged Fittings, Class 125, 150, and 300

ASME Codes & Standards

. . .	ASME Boiler and Pressure Vessel Code
B1.1	Unified Inch Screw Threads
B1.13M	Metric Screw Threads — M Profile
B1.20.1	Pipe Threads, General Purpose (Inch)
B1.20.3	Dryseal Pipe Threads (Inch)
B16.1	Cast Iron Pipe Flanges and Flanged Fittings — 25, 125, 250 & 800 Classes
B16.3	Malleable Iron Threaded Fittings
B16.4	Gray Iron Threaded Fittings
B16.5	Pipe Flanges and Flanged Fittings
B16.9	Factory-Made Wrought Buttwelding Fittings
B16.10	Face-to-Face and End-to-End Dimensions of Valves
B16.11	Forged Fittings, Socket-Welding and Threaded
B16.14	Ferrous Pipe Plugs, Bushings, and Locknuts With Pipe Threads
B16.15	Cast Bronze Threaded Fittings, Classes 125 and 250
B16.18	Cast Copper Alloy Solder-Joint Pressure Fittings
B16.20	Metallic Gaskets for Pipe Flanges — Ring Joint, Spiral Wound, and Jacketed
B16.21	Nonmetallic Flat Gaskets for Pipe Flanges
B16.22	Wrought Copper and Copper Alloy Solder Joint Pressure Fittings
B16.24	Cast Copper Alloy Pipe Flanges and Flanged Fittings — Class 150, 300, 400, 600, 900, 1500, and 2500
B16.25	Butt Welding Ends
B16.34	Valves — Flanged, Threaded, and Welding End
B16.42	Ductile Iron Pipe Flanges and Flanged Fittings — Classes 150 and 300
B16.47	Large Diameter Steel Flanges
B16.48	Steel Line Blanks
(07) B16.50	Wrought Copper and Copper Alloy Braze-Joint Pressure Fittings
B18.2.1	Square and Hex Bolts and Screws — Inch Series
B18.2.2	Square and Hex Nuts (Inch Series)

Table 126.1 Specifications and Standards (Cont'd)

ASME Codes & Standards (Cont'd)

B18.2.3.5M	Metric Hex Bolts
B18.2.3.6M	Metric Heavy Hex Bolts
B18.2.4.6M	Hex Nuts, Heavy, Metric
B18.21.1	Lock Washers (Inch Series)
B18.22M	Washers, Metric Plain
B18.22.1 [Note (2)]	Plain Washers
B31.3	Process Piping
B31.4	Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids
B31.8	Gas Transmission and Distribution Piping Systems
B36.10M	Welded and Seamless Wrought Steel Pipe
B36.19M	Stainless Steel Pipe
TDP-1	Recommended Practices for the Prevention of Water Damage to Steam Turbines Used for Electric Power Generation — Fossil Fueled Plants

AWS Specifications

A3.0	Standard Welding Terms and Definitions
QC1	Qualification and Certification of Welding Inspectors

AWWA and ANSI/AWWA Standards

C110/A21.10	Ductile-Iron and Gray-Iron Fittings, 3 in. Through 48 in. (76 mm Through 1200 mm), for Water and Other Liquids
C111/A21.11	Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fittings
C115/A21.15	Flanged Ductile-Iron Pipe With Threaded Flanges
C150/A21.50	Thickness Design of Ductile-Iron Pipe
C151/A21.51	Ductile-Iron Pipe, Centrifugally Cast, for Water
C153/A21.53	Ductile-Iron Compact Fittings, 3 in. Through 24 in. (76 mm Through 610 mm) and 54 in. Through 64 in. (1,400 mm Through 1,600 mm), for Water Service
C200	Steel Water Pipe—6 in. (150 mm) and Larger
C207	Steel Pipe Flanges for Waterworks Service—Sizes 4 in. Through 144 in. (100 mm Through 3,600 mm)
C208	Dimensions for Fabricated Steel Water Pipe Fittings
C300	Reinforced Concrete Pressure Pipe, Steel-Cylinder Type, for Water and Other Liquids (Includes Addendum C300a-93.)
C301	Prestressed Concrete Pressure Pipe, Steel-Cylinder Type, for Water and Other Liquids
C302	Reinforced Concrete Pressure Pipe, Noncylinder Type, for Water and Other Liquids
C304	Design of Prestressed Concrete Cylinder Pipe
C500	Metal-Seated Gate Valves for Water Supply Service
C504 [Note (1)]	Rubber Seated Butterfly Valves
C509	Resilient-Seated Gate Valves for Water Supply Service
C600	Installation of Ductile-Iron Water Mains and Their Appurtenances
C606	Grooved and Shouldered Joints

(A08)

National Fire Codes

NFPA 54/ANSI Z223.1	National Fuel Gas Code
NFPA 85	Boiler and Combustion Systems Hazards Code
NFPA 1963	Standard for Fire Hose Connections

PFI Standards

ES-16	Access Holes and Plugs for Radiographic Inspection of Pipe Welds
ES-24	Pipe Bending Methods, Tolerances, Process and Material Requirements

FCI Standard

79-1	Proof of Pressure Ratings for Pressure Regulators

Table 127.4.2 Reinforcement of Girth and Longitudinal Butt Welds

Thickness of Base Metal, in. (mm)	Maximum Thickness of Reinforcement for Design Temperature					
	> 750°F (400°C)		350°F–750°F (175°C–400°C)		< 350°F (175°C)	
	in.	mm	in.	mm	in.	mm
Up to $\frac{1}{8}$ (3.0), incl.	$\frac{1}{16}$	2.0	$\frac{3}{32}$	2.5	$\frac{3}{16}$	5.0
Over $\frac{1}{8}$ to $\frac{3}{16}$ (3.0 to 5.0), incl.	$\frac{1}{16}$	2.0	$\frac{1}{8}$	3.0	$\frac{3}{16}$	5.0
Over $\frac{3}{16}$ to $\frac{1}{2}$ (5.0 to 13.0), incl.	$\frac{1}{16}$	2.0	$\frac{5}{32}$	4.0	$\frac{3}{16}$	5.0
Over $\frac{1}{2}$ to 1 (13.0 to 25.0), incl.	$\frac{3}{32}$	2.5	$\frac{3}{16}$	5.0	$\frac{3}{16}$	5.0
Over 1 to 2 (25.0 to 50.0), incl.	$\frac{1}{8}$	3.0	$\frac{1}{4}$	6.0	$\frac{1}{4}$	6.0
Over 2 (50.0)	$\frac{5}{32}$	4.0	The greater of $\frac{1}{4}$ in. (6 mm) or $\frac{1}{8}$ times the width of the weld in inches (millimeters).			

GENERAL NOTES:

(a) For double welded butt joints, this limitation on reinforcement given above shall apply separately to both inside and outside surfaces of the joint.

(b) For single welded butt joints, the reinforcement limits given above shall apply to the outside surface of the joint only.

(c) The thickness of weld reinforcement shall be based on the thickness of the thinner of the materials being joined.

(d) The weld reinforcement thicknesses shall be determined from the higher of the abutting surfaces involved.

(e) Weld reinforcement may be removed if so desired.

the surface of the weld and the surface of either of the components shall not be less than 150 deg. Refer to para. 119.3(B) for additional concerns related to this design.

(B.3) When welding pipe to pipe, the surface of the weld shall, as a minimum, be flush with the outer surface of the pipe, except as permitted in para. 127.4.2(B.4).

(B.4) For welds made without the addition of filler metal, concavity shall be limited to $\frac{1}{32}$ in. (1 mm) below the outside surface of the pipe, but shall not encroach upon minimum required thickness.

(C) As-welded surfaces are permitted; however, the surface of welds shall be sufficiently free from coarse ripples, grooves, overlaps, abrupt ridges, and valleys to meet the following:

(C.1) The surface condition of the finished welds shall be suitable for the proper interpretation of radiographic and other nondestructive examinations when nondestructive examinations are required by Table 136.4. In those cases where there is a question regarding the surface condition on the interpretation of a radiographic film, the film shall be compared to the actual weld surface for interpretation and determination of acceptability.

(C.2) Reinforcements are permitted in accordance with Table 127.4.2.

(C.3) Undercuts shall not exceed $\frac{1}{32}$ in. (1.0 mm) and shall not encroach on the minimum required section thickness.

(C.4) If the surface of the weld requires grinding to meet the above criteria, care shall be taken to avoid reducing the weld or base material below the minimum required thickness.

(C.5) Concavity on the root side of a single welded circumferential butt weld is permitted when the resulting thickness of the weld is at least equal to the thickness of the thinner member of the two sections being joined and the contour of the concavity is smooth without sharp edges. The internal condition of the root surface of a girth weld, which has been examined by radiography, is acceptable only when there is a gradual change in the density, as indicated in the radiograph. If a girth weld is not designated to be examined by radiography, a visual examination may be performed at welds which are readily accessible.

127.4.3 Longitudinal Butt Welds. Longitudinal butt welds not covered by the applicable material specifications listed in Table 126.1 shall meet the requirements for girth butt welds in para. 127.4.2. For longitudinal welds and spiral welds in pipe intended for sustained operation in the creep range (see paras. 104.1.1 and 123.4, and Table 102.4.7), any welding using the SAW process shall use a flux with a basicity index ≥ 1.0. **(A08)**

127.4.4 Fillet Welds. In making fillet welds, the weld metal shall be deposited in such a way as to secure adequate penetration into the base metal at the root of the weld.

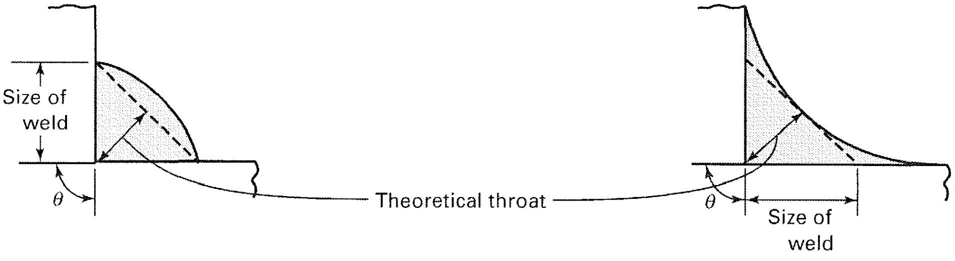
Fillet welds may vary from convex to concave. The size of a fillet weld is determined as shown in Fig. 127.4.4(A). Typical minimum fillet weld details for slip-on flanges and socket-welding components are shown in Figs. 127.4.4(B) and (C).

127.4.5 Seal Welds. Where seal welding of threaded joints is performed, threads shall be entirely covered by the seal weld. Seal welding shall be done by qualified welders.

127.4.8 Welded Branch Connections

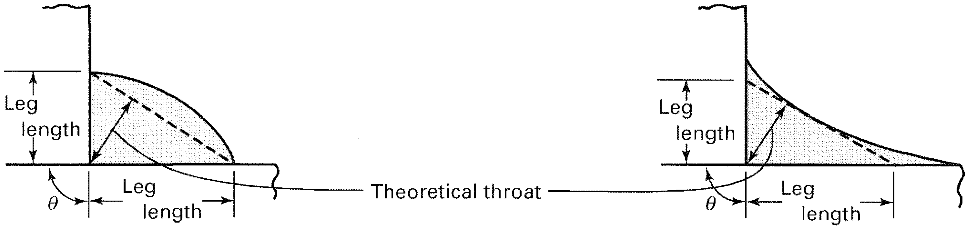
(A) Welded branch connections shall be made with full penetration welds, except as allowed in para. 127.4.8(F). Figures 127.4.8(A), (B), and (C) show typical details of branch connections with and without added

Fig. 127.4.4(A) Fillet Weld Size



(a) Convex Equal Leg Fillet Weld

(b) Concave Equal Leg Fillet Weld



(c) Convex Unequal Leg Fillet Weld

(d) Concave Unequal Leg Fillet Weld

GENERAL NOTES:

(a) The "size" of an equal leg fillet weld shall be described by the leg length of the largest inscribed isoceles triangle.

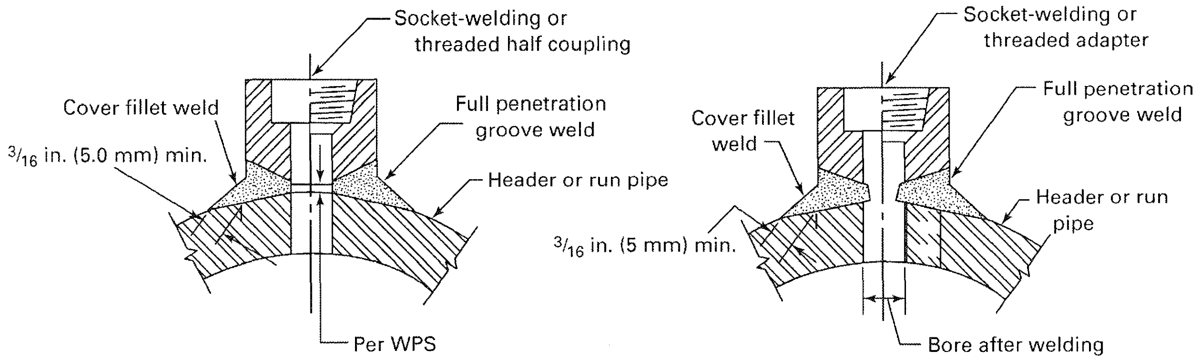
(b) The "size" of an unequal leg fillet weld shall be described using both leg lengths and their location on the members to be joined.

(c) Angle θ, as noted in the above figures, may vary from the 90 deg angle as shown based on the angle between the surfaces to be welded.

(d) For an equal leg fillet weld where the angle θ between the members being joined is 90 deg, the theoretical throat shall be 0.7 × leg length. For other fillet welds, the theoretical throat shall be based on the leg lengths and the angle θ between the members to be joined.

(e) For all fillet welds, particularly unequal leg fillet welds with angle θ less than 90 deg, the theoretical throat shall lie within the cross section of the deposited weld metal and shall not be less than the minimum distance through the weld.

Fig. 127.4.8(E) Typical Full Penetration Weld Branch Connections for NPS 3 and Smaller Half Couplings or Adapters

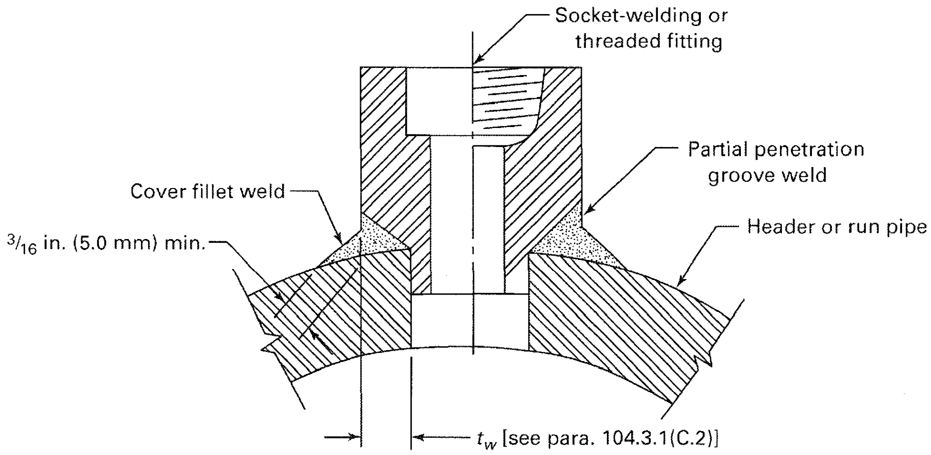

Socket-welding or threaded half coupling
Cover fillet weld
Full penetration groove weld
$^3/_{16}$ in. (5.0 mm) min.
Header or run pipe
Per WPS
Socket-welding or threaded adapter
Full penetration groove weld
Cover fillet weld
Header or run pipe
$^3/_{16}$ in. (5 mm) min.
Bore after welding

(a) Branch Connection Using ASME B16.11 Forged Steel Socket-Welding or Threaded Half Coupling [See Note (1)]

(b) Branch Connection Using Forged Steel Socket-Welding or Threaded Adapter for Pressure and Temperature Conditions Greater Than Permitted for ASME B16.11 Forged Steel Fittings

NOTE:
(1) Refer to para. 104.3.1(C.2) for branch connections not requiring reinforcement calculations.

Fig. 127.4.8(F) Typical Partial Penetration Weld Branch Connection for NPS 2 and Smaller Fittings


Socket-welding or threaded fitting
Partial penetration groove weld
Cover fillet weld
Header or run pipe
$^3/_{16}$ in. (5.0 mm) min.
t_w [see para. 104.3.1(C.2)]

hole. A good fit shall be provided between reinforcing rings or saddles and the parts to which they are attached.

(F) Branch connections NPS 2 and smaller which do not require reinforcements (see para. 104.3) may be constructed as shown in Fig. 127.4.8(F). The groove welds shall be finished with cover fillet welds with a minimum throat dimension not less than that shown in Fig. 127.4.8(F). This construction shall not be used at design temperatures greater than 750°F (400°C) nor at design pressures greater than 1,025 psi (7 100 kPa).

127.4.9 Attachment Welds. Structural attachments may be made by complete penetration, partial penetration, or fillet welds.

(A) Low energy capacitor discharge welding may be used for the welding of temporary attachments directly to pressure parts, provided that they be removed prior to subjecting the piping system to operating pressure or temperature. After their removal, the affected areas shall be examined in accordance with para. 136.4. Performance and procedure qualifications are not required.

This method of welding may also be used for the permanent attachment of nonstructural items, such as strain gages or thermocouples, provided that

(A.1) a welding procedure specification is prepared describing the capacitor discharge equipment, the materials to be joined, and the techniques of application; the qualification of the procedure is not required

(A.2) the minimum thickness of the material to which the attachment is to be made is 0.090 in. (2.3 mm)

(A.3) the power input is limited to less than 125 W-sec

127.4.10 Heat Treatment. Preheat and postweld heat treatment for welds shall be in accordance with para. 131 or 132 as applicable.

127.4.11 Repair Welding

(A) Defect Removal. All defects in welds or base materials requiring repair shall be removed by flame or arc gouging, grinding, chipping, or machining. Preheating may be required for flame or arc gouging on certain alloy materials of the air hardening type in order to prevent surface checking or cracking adjacent to the flame or arc gouged surface. When a defect is removed but welding repair is unnecessary, the surface shall be contoured to eliminate any sharp notches or corners. The contoured surface shall be reinspected by the same means originally used for locating the defect.

(B) Repair Welds. Repair welds shall be made in accordance with a WPS using qualified welders or welding operators (see para. 127.5), recognizing that the cavity to be repair welded may differ in contour and dimension from a normal joint preparation and may present different restraint conditions. The types, extent, and methods of examination shall be in accordance with Table 136.4. For repairs to welds the minimum examination shall be the same method that revealed the defect in the original weld. For repairs to base material, the minimum examination shall be the same as required for butt welds.

127.5 Qualification

127.5.1 General. Qualification of the WPS to be used, and of the performance of welders and welding operators, is required, and shall comply with the requirements of the ASME Boiler and Pressure Vessel Code (Section IX) except as modified herein.

Certain materials listed in Appendix A do not appear in ASME Section IX P-Number groups. Where these materials have been assigned P-Numbers in Appendix A, they may be welded under this Code for nonboiler external piping only without separate qualification as if they were listed in ASME Section IX.

127.5.2 Welding Responsibility. Each employer (see para. 100.2) shall be responsible for the welding performed by his/her organization and the performance of welders or welding operators employed by that organization.

127.5.3 Qualification Responsibility

(A) Procedures. Each employer shall be responsible for qualifying any WPS that he/she intends to have used by personnel of his/her organization. However, to avoid duplication of effort, and subject to approval of the Owner, a WPS qualified by a technically competent group or agency may be used:

(A.1) if the group or agency qualifying the WPS meets all of the procedure qualification requirements of this Code

(A.2) if the fabricator accepts the WPS thus qualified

(A.3) if the user of the WPS has qualified at least one welder using the WPS

(A.4) if the user of the WPS assumes specific responsibility for the procedure qualification work done for him/her by signing the records required by para. 127.6

All four of the above conditions shall be met before a WPS thus qualified may be used.

(A08) *(B) Welders and Welding Operators.* Each employer shall be responsible for qualifying all the welders and welding operators employed by him/her.

However, to avoid duplication of effort, he/she may accept a Welder/Welding Operator Performance Qualification (WPQ) made by a previous employer (subject to the approval of the Owner or his/her agent) on piping using the same or an equivalent procedure wherein the essential variables are within the limits established in Section IX, ASME Boiler and Pressure Vessel Code. An employer accepting such qualification tests by a previous employer shall obtain a copy of the original WPQ, showing the name of the employer by whom the welders or welding operators were qualified, the dates of such qualification, and evidence that the welder or welding operator has maintained qualification in accordance with QW-322 of Section IX, ASME Boiler and Pressure Vessel Code. The evidence of process usage to maintain continuity may be obtained from employers other than the original qualifying employer. The employer shall then prepare and sign the record required in para. 127.6 accepting responsibility for the ability of the welder or welding operator.

127.5.4 Standard Welding Procedure Specifications. Standard Welding Procedure Specifications published by the American Welding Society and listed in Appendix E of Section IX of the ASME Boiler and Pressure Vessel Code are permitted for Code construction within the limitations established by Article V of ASME Section IX.

127.6 Welding Records

The employer shall maintain a record (WPS and/or WPQ) signed by him/her, and available to the purchaser or his/her agent and the inspector, of the WPSs used and the welders and/or welding operators employed by him/her, showing the date and results of procedure and performance qualification.

Table 132 Postweld Heat Treatment (Cont'd)

(A08)

P-Number From Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness: Up to 2 in. (50 mm)	Holding Time Based on Nominal Thickness: Over 2 in. (50 mm)
P-No. 5B Gr. No. 1	1,300 (700) to 1,400 (760)	1 hr/in. (25 mm), 15 min minimum	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (50 mm)
Gr. No. 2	1,350 (730) to 1,425 (775)	1 hr/in. (25 mm), 30 min minimum	5 hr plus 15 min for each additional inch (25 mm) over 5 in. (125 mm)

GENERAL NOTES:

(a) If the nominal weld thickness is ≤ $\frac{1}{2}$ in. (13 mm), the minimum holding temperature is 1,325°F (720°C).

(b) For dissimilar metal welds (i.e., welds made between a P-No. 5B Group 2 and another lower chromium ferritic, austenitic, or nickel-based steel), if filler metal chromium content is less than 3.0% or if the filler metal is nickel-based or austenitic, the minimum holding temperature shall be 1,300°F (700°C).

(c) The maximum holding temperature above is to be used if the actual chemical composition of the matching filler metal used when making the weld is unknown. If the chemical composition of the matching filler metal is known, the maximum holding temperature can be increased as follows:

(1) If Ni + Mn < 1.50% but ≥ 1.0%, the maximum PWHT temperature is 1,450°F (790°C).

(2) If Ni + Mn < 1.0%, the maximum PWHT temperature is 1,470°F (800°C).

Explanatory Note to (c) Above: The lower transformation temperature for matching filler material is affected by alloy content, primarily the total of Ni + Mn. The maximum holding temperature has been set to avoid heat treatment in the intercritical zone.

(d) If a portion of the component is heated above the heat treatment temperature allowed above, one of the following actions shall be performed:

(1) The component in its entirety must be renormalized and tempered.

(2) If the maximum holding temperature in the Table or Note (c)(1) above is exceeded but does not exceed 1,470°F (800°C), the weld metal shall be removed and replaced.

(3) The portion of the component heated above 1,470°F (800°C) and at least 3 in. (75 mm) on either side of the overheated zone must be removed and be renormalized and tempered or replaced.

(4) The allowable stress shall be that for Grade 9 material (i.e., SA-213-T9, SA-335-P9, or equivalent product specification) at the design temperature, provided that the portion of the component heated to a temperature greater than that allowed above is reheat treated within the temperature range specified above.

P-Number From Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness: Up to 2 in. (50 mm)	Holding Time Based on Nominal Thickness: Over 2 in. (50 mm)
P-No. 6 Gr. Nos. 1, 2, 3	1,400 (760) to 1,475 (800)	1 hr/in. (25 mm), 15 min minimum	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (50 mm)

GENERAL NOTE: PWHT is not mandatory for P-No. 6 Type 410 material, provided all of the following conditions are met:

(a) the specified carbon content is not more than 0.08%

(b) the nominal material thickness is $\frac{3}{8}$ in. (10 mm) or less

(c) the weld is made with A-No. 8, A-No. 9, or F-No. 43 filler metal

Table 132 Postweld Heat Treatment (Cont'd)

P-Number From Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 7 Gr. Nos. 1, 2	1,350 (730) to 1,425 (775)	1 hr/in. (25 mm), 15 min minimum	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (50 mm)

GENERAL NOTES:

(a) In lieu of the cooling rate described in para. 132.5, P-No. 7 material cooling rate shall be not greater than 100°F (55°C) per hr in the range above 1,200°F (650°C), after which the cooling rate shall be sufficiently rapid to prevent embrittlement.

(b) PWHT is not mandatory for P-No. 7 Type 405 material, provided all of the following conditions are met:

  (1) the specified carbon content is not more than 0.08%
  (2) the nominal material thickness is $^3/_8$ in. (10 mm) or less
  (3) the weld is made with A-No. 8, A-No. 9, or F-No. 43 filler metal

P-Number From Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 8 Gr. Nos. 1, 2, 3, 4	None	None	None

GENERAL NOTE: PWHT is neither required nor prohibited for joints between P-No. 8 austenitic stainless steels.

P-Number From Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 9A Gr. No. 1	1,100 (600) to 1,200 (650)	1 hr/in. (25 mm), 15 min minimum	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (50 mm)

GENERAL NOTES:

(a) PWHT is not mandatory for P-No. 9A material when welds on pipe or attachment welds to pipe comply with all of the following conditions:

  (1) a nominal material thickness of $^1/_2$ in. (13.0 mm) or less
  (2) a specified carbon content of the material to be welded of 0.15% or less
  (3) a minimum preheat of 250°F (120°C) is maintained during welding

(b) When it is impractical to PWHT at the temperature range specified in Table 132, it is permissible to perform the PWHT of this material at lower temperatures for longer periods of time in accordance with Table 132.1, but the minimum PWHT shall not be less than 1,000°F (550°C).

P-Number From Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 9B Gr. No. 1	1,100 (600) to 1,175 (630)	1 hr/in. (25 mm), 15 min minimum	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (50 mm)

GENERAL NOTES:

(a) PWHT of P-No. 9B material is not mandatory for a nominal material thickness of $^5/_8$ in. (16.0 mm) or less provided the Welding Procedure Qualification has been made using material of thickness equal to or greater than the production weld.

(b) When it is impractical to PWHT at the temperature range specified in Table 132, it is permissible to perform the PWHT of this material at lower temperatures for longer periods of time in accordance with Table 132.1, but the minimum PWHT temperature shall not be less than 1,000°F (550°C).

Table 132 Postweld Heat Treatment (Cont'd)

P-Number From Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 10H Gr. No. 1	. . .	. . .	. . .

GENERAL NOTE: Postweld heat treatment is neither required nor prohibited. If any heat treatment is performed after forming or welding, it shall be performed within the temperature range listed below for the particular alloy, followed by a rapid cool:

Alloy S31803	1,870°F–2,010°F
Alloy S32550	1,900°F–2,050°F
Alloy S32750	1,880°F–2,060°F
All others	1,800°F–1,900°F

P-Number From Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 10I Gr. No. 1	1,350 (730) to 1,500 (815)	1 hr/in. (25 mm), 15 min minimum	1 hr/in. (25 mm)

GENERAL NOTES:

(a) In lieu of the cooling rate described in para. 132.5, the P-No. 10I material cooling rate shall be not greater than 100°F (55°C) per hr in the range above 1,200°F (650°C), after which the cooling rate shall be sufficiently rapid to prevent embrittlement.

(b) Postweld heat treatment is neither required nor prohibited for a nominal thickness of $\frac{1}{2}$ in. (13 mm) or less.

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(A08)

Table 136.4 Mandatory Minimum Nondestructive Examinations for Pressure Welds or Welds to Pressure-Retaining Components

	Piping Design Conditions and Nondestructive Examination		
Type Weld	Temperatures Over 750°F (400°C) and at All Pressures	Temperatures Between 350°F (175°C) and 750°F (400°C) Inclusive, With All Pressures Over 1,025 psig [7 100 kPa (gage)]	All Others
Butt welds (girth and longitudinal) [Note (1)]	RT or UT for over NPS 2. MT or PT for NPS 2 and less [Note (2)].	RT or UT for over NPS 2 with thickness over $^3/_4$ in. (19.0 mm). VT for all sizes with thickness $^3/_4$ in. (19.0 mm) or less.	Visual for all sizes and thicknesses
Welded branch connections (size indicated is branch size) [Notes (3) and (4)]	RT or UT for over NPS 4. MT or PT for NPS 4 and less [Note (2)].	RT or UT for branch over NPS 4 and thickness of branch over $^3/_4$ in. (19.0 mm) MT or PT for branch NPS 4 and less with thickness of branch over $^3/_4$ in. (19 mm) VT for all sizes with branch thickness $^3/_4$ in. (19.0 mm) or less	VT for all sizes and thicknesses
Fillet, socket, attachment, and seal welds	PT or MT for all sizes and thicknesses [Note (5)]	VT for all sizes and thicknesses	VT for all sizes and thicknesses

GENERAL NOTES:

(a) All welds shall be given a visual examination in addition to the type of specific nondestructive examination specified.

(b) NPS — nominal pipe size.

(c) RT — radiographic examination; UT — ultrasonic examination; MT — magnetic particle examination; PT — liquid penetrant examination; VT — visual examination.

(d) For nondestructive examinations of the pressure retaining component, refer to the standards listed in Table 126.1 or manufacturing specifications.

(e) Acceptance standards for nondestructive examinations performed are as follows: MT — see para. 136.4.3; PT — see para. 136.4.4; VT — see para. 136.4.2; RT — see para. 136.4.5; UT — see para. 136.4.6.

(f) All longitudinal welds and spiral welds in pipe intended for sustained operation in the creep range (see paras. 104.1.1 and 123.4, and Table 102.4.7) must receive and pass a 100% volumetric examination (RT or UT) per the applicable material specification or in accordance with para. 136.4.5 or 136.4.6.

NOTES:

(1) The thickness of butt welds is defined as the thicker of the two abutting ends after end preparation.

(2) RT may be used as an alternative to PT or MT when it is performed in accordance with para. 136.4.5.

(3) RT or UT of branch welds shall be performed before any nonintegral reinforcing material is applied.

(4) In lieu of volumetric examination (RT, UT) of welded branch connections when required above, surface examination (PT, MT) is acceptable and, when used, shall be performed at the lesser of one-half of the weld thickness or each $^1/_2$ in. (12.5 mm) of weld thickness and all accessible final weld surfaces.

(5) Fillet welds not exceeding $^1/_4$ in. (6 mm) throat thickness which are used for the permanent attachment of nonpressure retaining parts are exempt from the PT or MT requirements of the above Table.

Table 136.4.1 Weld Imperfections Indicated by Various Types of Examination

Imperfection	Visual	Magnetic Particle	Liquid Penetrant	Radiography	Ultrasonic
Crack — surface	X [Note (1)]	X [Note (1)]	X [Note (1)]	X	X
Crack — internal	. . .	. . .	. . .	X	X
Undercut — surface	X [Note (1)]	X [Note (1)]	X [Note (1)]	X	. . .
Weld reinforcement	X [Note (1)]	. . .	. . .	X	. . .
Porosity	X [Notes (1), (2)]	X [Notes (1), (2)]	X [Notes (1), (2)]	X	. . .
Slag inclusion	X [Note (2)]	X [Note (2)]	X [Note (2)]	X	X
Lack of fusion (on surface)	X [Notes (1), (2)]	X [Notes (1), (2)]	X [Notes (1), (2)]	X	X
Incomplete penetration	X [Note (3)]	X [Note (3)]	X [Note (3)]	X	X

NOTES:

(1) Applies when the outside surface is accessible for examination and/or when the inside surface is readily accessible.

(2) Discontinuities are detectable when they are open to the surface.

(3) Applies *only* when the inside surface is readily accessible.

(B) Acceptance Standards. Indications whose major dimensions are greater than $^1/_{16}$ in. (2.0 mm) shall be considered relevant. The following relevant indications are unacceptable:

(B.1) any cracks or linear indications

(B.2) rounded indications with dimensions greater than $^3/_{16}$ in. (5.0 mm)

(B.3) four or more rounded indications in a line separated by $^1/_{16}$ in. (2.0 mm) or less, edge to edge

(B.4) ten or more rounded indications in any 6 in.^{2} (3 870 mm^2) of surface with the major dimension of this area not to exceed 6 in. (150 mm) with the area taken in the most unfavorable location relative to the indications being evaluated

136.4.4 Liquid Penetrant Examination. Whenever required by this Chapter (see Table 136.4), liquid penetrant examination shall be performed in accordance with the methods of Article 6, Section V, of the ASME Boiler and Pressure Vessel Code.

(A) Evaluation of Indications

(A.1) Mechanical discontinuities at the surface will be indicated by bleeding out of the penetrant; however, localized surface imperfections, such as may occur from machining marks or surface conditions, may produce similar indications which are nonrelevant to the detection of unacceptable discontinuities.

(A.2) Any indication that is believed to be nonrelevant shall be regarded as a defect and shall be reexamined to verify whether or not actual defects are present. Surface conditioning may precede the reexamination. Nonrelevant indications and broad areas of pigmentation which would mask indications of defects are unacceptable.

(A.3) Relevant indications are those which result from mechanical discontinuities. Linear indications are those indications in which the length is more than three times the width. Rounded indications are indications which are circular or elliptical with the length less than three times the width.

(A.4) An indication of a discontinuity may be larger than the discontinuity that causes it; however, the size of the indication and not the size of the discontinuity is the basis of acceptance or rejection.

(B) Acceptance Standards. Indications whose major dimensions are greater than $^1/_{16}$ in. (2.0 mm) shall be considered relevant. The following relevant indications are unacceptable:

(B.1) any cracks or linear indications

(B.2) rounded indications with dimensions greater than $^3/_{16}$ in. (5.0 mm)

(B.3) four or more rounded indications in a line separated by $^1/_{16}$ in. (2.0 mm) or less edge to edge

(B.4) ten or more rounded indications in any 6 in.^{2} (3 870 mm^2) of surface with the major dimension of this area not to exceed 6 in. (150 mm) with the area taken in the most unfavorable location relative to the indications being evaluated

136.4.5 Radiography. When required by this Chapter (see Table 136.4), radiographic examination shall be performed in accordance with Article 2 of Section V of the ASME Boiler and Pressure Vessel Code, except that the requirements of T-285 are to be used as a guide but not for the rejection of radiographs unless the geometrical unsharpness exceeds 0.07 in. (2.0 mm).

(A) Acceptance Standards. Welds that are shown by radiography to have any of the following types of discontinuities are unacceptable:

(A.1) any type of crack or zone of incomplete fusion or penetration

(A.2) any other elongated indication which has a length greater than

(A.2.1) $^1/_4$ in. (6.0 mm) for t up to $^3/_4$ in. (19.0 mm), inclusive

Table A-2 Low and Intermediate Alloy Steel (Cont'd)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																			
−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1,000	1,050	1,100	1,150	1,200	Grade	Spec. No.
Seamless Pipe and Tube (Cont'd)																			
17.1	16.8	16.5	16.5	16.5	16.3	16.0	15.8	15.5	15.3	14.9	14.5	*11.3*	*7.2*	*4.5*	*2.8*	...	...	FP12	A 369
17.1	17.1	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	*16.0*	*12.0*	*9.0*	*7.0*	*5.5*	*4.0*	...	...	FP21	
17.1	17.1	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	*16.6*	*13.6*	*10.8*	*8.0*	*5.7*	*3.8*	...	...	FP22	
18.6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	V	A 714
Centrifugally Cast Pipe																			
15.8	15.8	15.8	15.8	15.8	15.8	15.8	15.6	15.2	14.8	14.4	...	...	...	...	...	...	...	CP1	A 426
14.5	14.5	14.5	14.5	14.4	13.9	13.7	13.3	13.1	12.7	12.3	11.8	*7.8*	*5.0*	...	...	...	...	CP2	
21.9	21.8	21.2	21.0	20.9	20.6	20.3	19.9	19.3	18.5	*12.2*	*9.3*	*6.8*	*4.9*	*3.6*	*2.5*	*1.5*	*0.85*	CP5	
14.6	14.5	14.1	14.0	14.0	13.8	13.5	13.3	12.9	12.4	11.8	*9.3*	*6.8*	*4.9*	*3.6*	*2.5*	*1.5*	*0.85*	CP5b	
21.9	21.8	21.2	21.0	20.9	20.7	20.3	19.9	19.3	18.5	17.7	*14.0*	*9.4*	*6.3*	*4.3*	*2.8*	*1.9*	*1.3*	CP9	A 426
17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	16.7	16.3	15.9	*11.6*	*7.9*	*5.4*	*3.6*	*2.4*	...	...	CP11	
14.5	14.3	14.0	13.8	13.3	12.9	12.8	12.6	12.4	12.2	11.9	11.6	*9.6*	*6.1*	*3.8*	*2.4*	...	...	CP12	A 426
14.5	14.5	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	*13.6*	*10.2*	*7.7*	*6.0*	*4.7*	*3.4*	...	...	CP21	
17.0	17.0	16.7	16.5	16.4	16.3	16.2	16.0	15.7	15.2	14.6	*13.4*	*9.7*	*6.6*	*4.3*	*2.7*	...	...	CP22	
Electric Resistance Welded Pipe																			
15.8	15.8	15.8	15.8	15.8	14.9	14.2	...	...	...	...	...	...	...	...	...	...	...	3	A 333
15.8	15.8	15.8	15.8	15.8	14.9	14.2	...	...	...	...	...	...	...	...	...	...	...	7	
15.3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	9	
15.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	V	A 714
Electric Fusion Welded Pipe — Filler Metal Added																			
16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.6	16.1	...	...	...	...	...	...	...	L65	A 672
18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.4	17.9	...	...	...	...	...	...	...	L65	
18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	17.9	17.4	...	...	...	...	...	...	...	L70	A 672
20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	19.9	19.3	...	...	...	...	...	...	...	L70	
19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	18.7	...	...	...	...	...	...	...	L75	A 672
21.4	21.4	21.4	21.4	21.4	21.4	21.4	21.4	21.4	21.4	20.7	...	...	...	...	...	...	...	L75	
16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.6	16.1	...	...	...	...	...	...	...	CM-65	A 691
18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.4	17.9	...	...	...	...	...	...	...	CM-65	
18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	17.9	17.4	...	...	...	...	...	...	...	CM-70	A 691
20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	19.9	19.3	...	...	...	...	...	...	...	CM-70	
19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	18.7	...	...	...	...	...	...	...	CM-75	A 691
21.4	21.4	21.4	21.4	21.4	21.4	21.4	21.4	21.4	21.4	20.7	...	...	...	...	...	...	...	CM-75	
14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	13.8	*12.9*	*8.3*	*5.3*	...	...	...	...	½CR	A 691
15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.3	*14.3*	*9.2*	*5.9*	...	...	...	...	½CR	
18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	17.6	16.7	*8.3*	*5.3*	...	...	...	...	½CR	
20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	19.5	18.6	*9.2*	*5.9*	...	...	...	...	½CR	

Table A-2 Low and Intermediate Alloy Steel (Cont'd)

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
Electric Fusion Welded Pipe — Filler Metal Added (Cont'd)								
A 691	1CR	20,23	1Cr–½Mo	4	(1)(11)	55	33	0.90
	1CR	21,22	1Cr–½Mo	4	(1)(11)	55	33	1.00
	1CR	20,23,30,33,40,43	1Cr–½Mo	4	(1)(12)	65	40	0.90
	1CR	21,22,31,32,41,42	1Cr–½Mo	4	(1)(12)	65	40	1.00
A 691	1¼CR	20,23	1¼Cr–½Mo–Si	4	(1)(11)	60	35	0.90
	1¼CR	21,22	1¼Cr–½Mo–Si	4	(1)(11)	60	35	1.00
	1¼CR	20,23,30,33,40,43	1¼Cr–½Mo–Si	4	(1)(12)	75	45	0.90
	1¼CR	21,22,31,32,41,42	1¼Cr–½Mo–Si	4	(1)(12)	75	45	1.00
A 691	2¼CR	20,23	2¼Cr–1Mo	5A	(1)(11)(17)	60	30	0.90
	2¼CR	21,22	2¼Cr–1Mo	5A	(1)(11)(17)	60	30	1.00
	2¼CR	20,23,30,33,40,43	2¼Cr–1Mo	5A	(1)(12)(17)	75	45	0.90
	2¼CR	21,22,31,32,41,42	2¼Cr–1Mo	5A	(1)(12)(17)	75	45	1.00
A 691	3CR	20,23	3Cr–1Mo	5A	(1)(11)	60	30	0.90
	3CR	21,22	3Cr–1Mo	5A	(1)(11)	60	30	1.00
	3CR	20,23,30,33,40,43	3Cr–1Mo	5A	(1)(12)	75	45	0.90
	3CR	21,22,31,32,41,42	3Cr–1Mo	5A	(1)(12)	75	45	1.00
A 691	5CR	20,23	5Cr–½Mo	5B	(1)(11)	60	30	0.90
	5CR	21,22	5Cr–½Mo	5B	(1)(11)	60	30	1.00
	5CR	20,23,30,33,40,43	5Cr–½Mo	5B	(1)(12)	75	45	0.90
	5CR	21,22,31,32,41,42	5Cr–½Mo	5B	(1)(12)	75	45	1.00
(A08) A 691	91	40,43,50,53	9Cr–1Mo–V	5B	(1)(12)	85	60	0.90
(A08)	91	41,42,51,52	9Cr–1Mo–V	5B	(1)(12)	85	60	1.00
Plate								
A 387	2	1	½Cr–½Mo	3	. . .	55	33	1.00
	2	2	½Cr–½Mo	3	(1)	70	45	1.00
	5	1	5Cr–½Mo	5B	. . .	60	30	1.00
	5	2	5Cr–½Mo	5B	(1)	75	45	1.00
A 387	11	1	1¼Cr–½Mo–Si	4	. . .	60	35	1.00
	11	2	1¼Cr–½Mo–Si	4	. . .	75	45	1.00
	12	1	1Cr–½Mo	4	. . .	55	33	1.00
	12	2	1Cr–½Mo	4	. . .	65	40	1.00
A 387	21	1	3Cr–1Mo	5A	. . .	60	30	1.00
	21	2	3Cr–1Mo	5A	. . .	75	45	1.00
	22	1	2¼Cr–1Mo	5A	(17)	60	30	1.00
	22	2	2¼Cr–1Mo	5A	(17)	75	45	1.00
A 387	91	2	9Cr–1Mo–V	5B	(19)	85	60	1.00
	91	2	9Cr–1Mo–V	5B	(20)	85	60	1.00

Table A-3 Stainless Steels (Cont'd)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																			
−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1,000	1,050	1,100	1,150	1,200	Type or Grade	Spec. No.
Seamless Pipe and Tube (Cont'd) Austenitic (Cont'd)																			
20.0	16.7	15.0	13.8	12.9	12.3	12.0	11.7	11.5	11.2	11.0	10.8	10.6	10.4	10.1	*9.8*	*7.7*	*6.1*	TP304	A 376
20.0	20.0	18.9	18.3	17.5	16.6	16.2	15.8	15.5	15.2	14.9	14.6	14.3	14.0	*12.4*	*9.8*	*7.7*	*6.1*	TP304	
20.0	16.7	15.0	13.8	12.9	12.3	12.0	11.7	11.5	11.2	11.0	10.8	10.6	10.4	10.1	*9.8*	*7.7*	*6.1*	TP304H	
20.0	20.0	18.9	18.3	17.5	16.6	16.2	15.8	15.5	15.2	14.9	14.6	14.3	14.0	*12.4*	*9.8*	*7.7*	*6.1*	TP304H	
22.9	19.1	16.7	15.1	14.0	13.3	13.0	12.8	12.5	12.3	12.1	11.8	11.6	11.3	11.0	*9.8*	*7.7*	*6.1*	TP304N	
22.9	22.9	21.7	20.3	18.9	17.9	17.5	17.2	16.9	16.6	16.3	16.0	15.6	15.2	*12.4*	*9.8*	*7.7*	*6.1*	TP304N	
20.0	17.3	15.6	14.3	13.3	12.6	12.3	12.1	11.9	11.8	11.6	11.5	11.4	11.3	11.2	11.1	*9.8*	*7.4*	TP316	A 376
20.0	20.0	20.0	19.3	18.0	17.0	16.6	16.3	16.1	15.9	15.7	15.6	15.4	15.3	15.1	*12.4*	*9.8*	*7.4*	TP316	
20.0	17.3	15.6	14.3	13.3	12.6	12.3	12.1	11.9	11.8	11.6	11.5	11.4	11.3	11.2	11.1	*9.8*	*7.4*	TP316H	
20.0	20.0	20.0	19.3	18.0	17.0	16.6	16.3	16.1	15.9	15.7	15.6	15.4	15.3	15.1	*12.4*	*9.8*	*7.4*	TP316H	
22.9	20.7	19.0	17.6	16.5	15.6	15.2	14.9	14.5	14.2	13.9	13.7	13.4	13.2	12.9	*12.3*	*9.8*	*7.4*	TP316N	
22.9	22.9	22.0	21.5	21.2	21.0	20.5	20.0	19.6	19.2	18.8	18.5	18.1	17.8	*15.8*	*12.3*	*9.8*	*7.4*	TP316N	
20.0	18.0	16.5	15.3	14.3	13.5	13.2	13.0	12.7	12.6	12.4	12.3	12.1	12.0	*9.6*	*6.9*	*5.0*	*3.6*	TP321	A 376
20.0	20.0	19.1	18.7	18.7	18.3	17.9	17.5	17.2	16.9	16.7	16.5	16.4	*16.2*	*9.6*	*6.9*	*5.0*	*3.6*	TP321	
20.0	18.0	16.5	15.3	14.3	13.5	13.2	13.0	12.7	12.6	12.4	12.3	12.1	12.0	11.9	*9.1*	*6.9*	*5.4*	TP321H	
20.0	20.0	19.1	18.7	18.7	18.3	17.9	17.5	17.2	16.9	16.7	16.5	16.4	16.2	*12.3*	*9.1*	*6.9*	*5.4*	TP321H	
20.0	18.4	17.1	16.0	15.0	14.3	14.0	13.8	13.7	13.6	13.5	13.4	13.4	13.4	*12.1*	*9.1*	*6.1*	*4.4*	TP347	A 376
20.0	20.0	18.8	17.8	17.2	16.9	16.8	16.8	16.8	16.8	16.8	16.7	16.6	*16.0*	*12.1*	*9.1*	*6.1*	*4.4*	TP347	
20.0	18.4	17.1	16.0	15.0	14.3	14.0	13.8	13.7	13.6	13.5	13.4	13.4	13.4	13.4	13.3	*10.5*	*7.9*	TP347H	
20.0	20.0	18.8	17.8	17.1	16.9	16.8	16.8	16.8	16.8	16.8	16.7	16.6	16.4	16.2	*14.1*	*10.5*	*7.9*	TP347H	
20.0	18.4	17.1	16.0	15.0	14.3	14.0	13.8	13.7	13.6	13.5	13.4	13.4	13.4	*12.1*	*9.1*	*6.1*	*4.4*	TP348	A 376
20.0	20.0	18.8	17.8	17.2	16.9	16.8	16.8	16.8	16.8	16.8	16.7	16.6	*16.0*	*12.1*	*9.1*	*6.1*	*4.4*	TP348	
20.0	16.7	15.0	13.8	12.9	12.3	12.0	11.7	11.5	11.2	11.0	10.8	10.6	10.4	10.1	*9.8*	*7.7*	*6.1*	FP304	A 430
20.0	18.9	17.7	17.1	16.9	16.6	16.2	15.8	15.5	15.2	14.9	14.6	14.3	14.0	*12.4*	*9.8*	*7.7*	*6.1*	FP304	
20.0	16.7	15.0	13.8	12.9	12.3	12.0	11.7	11.5	11.2	11.0	10.8	10.6	10.4	10.1	*9.8*	*7.7*	*6.1*	FP304H	
20.0	18.9	17.7	17.1	16.9	16.6	16.2	15.8	15.5	15.2	14.9	14.6	14.3	14.0	*12.4*	*9.8*	*7.7*	*6.1*	FP304H	
21.4	19.1	16.7	15.1	14.0	13.3	13.0	12.8	12.5	12.3	12.1	11.8	11.6	11.3	11.0	*9.8*	*7.7*	*6.1*	FP304N	
21.4	21.4	20.4	19.6	18.9	17.9	17.5	17.2	16.9	16.6	16.3	16.0	15.6	15.2	*12.4*	*9.8*	*7.7*	*6.1*	FP304N	
20.0	17.3	15.6	14.3	13.3	12.6	12.3	12.1	11.9	11.8	11.6	11.5	11.4	11.3	11.2	11.1	*9.8*	*7.4*	FP316	A 430
20.0	20.0	19.4	19.2	18.0	17.0	16.6	16.3	16.1	15.9	15.7	15.6	15.4	15.3	15.1	*12.4*	*9.8*	*7.4*	FP316	
20.0	17.3	15.6	14.3	13.3	12.6	12.3	12.1	11.9	11.8	11.6	11.5	11.4	11.3	11.2	11.1	*9.8*	*7.4*	FP316H	
20.0	20.0	19.4	19.2	18.0	17.0	16.6	16.3	16.1	15.9	15.7	15.6	15.4	15.3	15.1	*12.4*	*9.8*	*7.4*	FP316H	
21.4	20.7	19.0	17.6	16.5	15.6	15.2	14.9	14.5	14.2	13.9	13.7	13.4	13.2	12.9	*12.3*	*9.8*	*7.4*	FP316N	
21.4	21.4	20.6	20.1	19.9	19.9	19.9	19.9	19.6	19.2	18.8	18.5	18.1	17.8	*15.8*	*12.3*	*9.8*	*7.4*	FP316N	
20.0	18.0	16.5	15.3	14.3	13.5	13.2	13.0	12.7	12.6	12.4	12.3	12.1	12.0	*9.6*	*6.9*	*5.0*	*3.6*	FP321	A 430
20.0	19.0	17.8	17.5	17.5	17.5	17.5	17.5	17.2	16.9	16.7	16.5	16.4	*14.9*	*9.6*	*6.9*	*5.0*	*3.6*	FP321	
20.0	18.0	16.5	15.3	14.3	13.5	13.2	13.0	12.7	12.6	12.4	12.3	12.1	12.0	11.9	*9.1*	*6.9*	*5.4*	FP321H	
20.0	19.0	17.8	17.5	17.5	17.5	17.5	17.5	17.2	16.9	16.7	16.5	16.4	16.2	*12.3*	*9.1*	*6.9*	*5.4*	FP321H	
20.0	18.4	17.1	16.0	15.0	14.3	14.0	13.8	13.7	13.6	13.5	13.4	13.4	13.4	*12.1*	*9.1*	*6.1*	*4.4*	FP347	A 430
20.0	19.1	17.6	16.6	16.0	15.8	15.7	15.7	15.7	15.7	15.7	15.6	15.5	15.3	*12.1*	*9.1*	*6.1*	*4.4*	FP347	
20.0	18.4	17.1	16.0	15.0	14.3	14.0	13.8	13.7	13.6	13.5	13.4	13.4	13.4	13.4	13.3	*10.5*	*7.9*	FP347H	
20.0	19.1	17.6	16.6	16.0	15.7	15.7	15.7	15.7	15.7	15.7	15.6	15.5	15.3	15.1	*14.1*	*10.5*	*7.9*	FP347H	
31.4	31.3	29.5	28.6	28.2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	A 789
31.4	31.3	29.5	28.6	28.2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	A 790

Table A-3 Stainless Steels (Cont'd)

	Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
	Seamless Pipe and Tube (Cont'd)									
	Ferritic/Martensitic									
	A 268	TP405	. . .	S40500	12Cr–A1	7	(3)	60	30	1.00
		TP410	. . .	S41000	13Cr	6	. . .	60	30	1.00
		TP429	. . .	S42900	15Cr	6	(3)	60	35	1.00
		TP430	. . .	S43000	17Cr	7	(3)	60	35	1.00
		TPXM-27	. . .	S44627	26Cr–1Mo	10I	(1)(2)	65	40	1.00
		TP446-1	. . .	S44600	27Cr	10I	. . .	70	40	1.00
		TPXM-33	. . .	S44626	27Cr–1Mo–Ti	10I	(2)	68	45	1.00
	A 731	TPXM-27	. . .	S44627	27Cr–1Mo	10I	(2)	65	40	1.00
		TPXM-33	. . .	S44626	27Cr–1Mo–Ti	10I	(2)	65	40	1.00
	Ferritic/Austenitic									
	A 789	S31803	. . .	S31803	22Cr–5.5Ni–3Mo–N	10H	(1)(33)(34)	90	65	1.00
(A08)		S32205	. . .	S32205	22Cr–5.5Ni–3Mo–N	10H	(1)(33)(34)	95	70	1.00
(A08)		S32750	. . .	S32750	25Cr–7Ni–4Mo–N	10H	(1)(33)(39)	116	80	1.00
	A 790	S31803	. . .	S31803	22Cr–5.5Ni–3Mo–N	10H	(1)(33)(34)	90	65	1.00
(A08)		S32205	. . .	S32205	22Cr–5.5Ni–3Mo–N	10H	(1)(33)(34)	90	65	1.00
(A08)		S32750	. . .	S32750	25Cr–7Ni–4Mo–N	10H	(1)(33)(39)	116	80	1.00
	Centrifugally Cast Pipe									
	Austenitic									
	A 451	CPF8	. . .	J92600	18Cr–8Ni	8	(1)(8)(10)(26)	70	30	0.85
		CPF8	. . .	J92600	18Cr–8Ni	8	(1)(8)(9)(10)(26)	70	30	0.85
		CPF8C	. . .	J92710	18Cr–10Ni–Cb	8	(1)(8)(10)(26)	70	30	0.85
		CPF8C	. . .	J92710	18Cr–10Ni–Cb	8	(1)(8)(9)(10)(26)	70	30	0.85
		CPF8M	. . .	J92900	18Cr–9Ni–2Mo	8	(1)(8)(13)(26)	70	30	0.85
		CPF8M	. . .	J92900	18Cr–9Ni–2Mo	8	(1)(8)(9)(13)(26)	70	30	0.85
	A 451	CPH8	. . .	J93400	25Cr–12Ni	8	(1)(8)(10)(26)	65	28	0.85
		CPH8	. . .	J93400	25Cr–12Ni	8	(1)(8)(9)(10)(26)	65	28	0.85
		CPH10	. . .	J93410	25Cr–12Ni	8	(1)(6)(8)(10)(26)	(70)	30	0.85
		CPH10	. . .	J93410	25Cr–12Ni	8	(1)(6)(8)(9)(10)(26)	(70)	30	0.85
	A 451	CPH20	. . .	J93402	25Cr–12Ni	8	(1)(6)(8)(10)(26)	(70)	30	0.85
		CPH20	. . .	J93402	25Cr–12Ni	8	(1)(6)(8)(9)(10)(26)	(70)	30	0.85
		CPK20	. . .	J94202	25Cr–20Ni	8	(1)(8)(10)(26)	65	28	0.85
		CPK20	. . .	J94202	25Cr–20Ni	8	(1)(8)(9)(10)(26)	65	28	0.85
	A 452	TP304H	. . .	J92590	18Cr–8Ni	8	(1)(8)(26)	75	30	0.85
		TP304H	. . .	J92590	18Cr–8Ni	8	(1)(8)(9)(26)	75	30	0.85
		TP316H	. . .	J92920	16Cr–12Ni–2Mo	8	(1)(8)(26)	75	30	0.85
		TP316H	. . .	J92920	16Cr–12Ni–2Mo	8	(1)(8)(9)(26)	75	30	0.85
		TP347H	. . .	J92660	18Cr–10Ni–Cb	8	(1)(8)(26)	75	30	0.85
		TP347H	. . .	J92660	18Cr–10Ni–Cb	8	(1)(8)(9)(26)	75	30	0.85
	Welded Pipe and Tube — Without Filler Metal									
	Austenitic									
	A 249	TP304	. . .	S30400	18Cr–8Ni	8	(10)	75	30	0.85
		TP304	. . .	S30400	18Cr–8Ni	8	(9)(10)	75	30	0.85
		TP304H	. . .	S30409	18Cr–8Ni	8	. . .	75	30	0.85
		TP304H	. . .	S30409	18Cr–8Ni	8	(9)	75	30	0.85
	A 249	TP304L	. . .	S30403	18Cr–8Ni	8	(1)	70	25	0.85
		TP304L	. . .	S30403	18Cr–8Ni	8	(1)(9)	70	25	0.85
		TP304N	. . .	S30451	18Cr–8Ni–N	8	(10)	80	35	0.85
		TP304N	. . .	S30451	18Cr–8Ni–N	8	(9)(10)	80	35	0.85

Table A-3 Stainless Steels (Cont'd)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																				
−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1,000	1,050	1,100	1,150	1,200	Type or Grade	Spec. No.	
Seamless Pipe and Tube (Cont'd) Ferritic/Martensitic																				
17.1	17.1	16.8	16.5	16.3	15.9	15.6	15.2	...	...	...	...	...	...	...	...	...	...	TP405	A 268	
17.1	17.1	16.8	16.5	16.3	15.9	15.6	15.2	...	...	...	...	...	...	...	...	...	...	TP410		
17.1	17.1	16.8	16.5	16.3	15.9	15.6	15.2	...	...	...	...	...	...	...	...	...	...	TP429		
17.1	17.1	16.8	16.5	16.3	15.9	15.6	15.2	...	...	...	...	...	...	...	...	...	...	TP430		
18.6	18.6	18.3	18.1	18.1	18.1	18.1	...	...	...	...	...	...	...	...	...	...	...	TPXM-27		
20.0	20.0	19.3	18.8	18.4	17.9	17.7	...	...	...	...	...	...	...	...	...	...	...	TP446-1		
19.4	19.4	19.3	19.0	18.8	18.4	18.1	...	...	...	...	...	...	...	...	...	...	...	TPXM-33		
18.6	18.6	18.3	18.1	18.1	18.1	18.1	...	...	...	...	...	...	...	...	...	...	...	TPXM-27	A 731	
18.6	18.6	18.4	18.2	18.0	17.6	17.3	...	...	...	...	...	...	...	...	...	...	...	TPXM-33		
Ferritic/Austenitic																				
25.7	25.7	24.8	23.9	23.3	23.1	...	...	...	...	...	...	...	...	...	...	...	...	S31803	A 789	
27.1	27.1	26.2	25.2	24.6	24.3	...	...	...	...	...	...	...	...	...	...	...	...	S32205		**(A08)**
33.1	33.0	31.2	30.1	29.6	29.4	...	...	...	...	...	...	...	...	...	...	...	...	S32750		**(A08)**
25.7	25.7	24.8	23.9	23.3	23.1	...	...	...	...	...	...	...	...	...	...	...	...	S31803	A 790	
25.7	25.7	24.8	23.9	23.3	23.1	...	...	...	...	...	...	...	...	...	...	...	...	S32205		**(A08)**
33.1	33.0	31.2	30.1	29.6	29.4	...	...	...	...	...	...	...	...	...	...	...	...	S32750		**(A08)**
Centrifugally Cast Pipe Austenitic																				
17.0	14.2	12.7	11.7	11.0	10.5	10.2	9.9	9.8	9.5	9.4	9.2	9.0	8.8	*8.1*	*6.4*	*5.1*	*4.1*	CPF8	A 451	
17.0	16.1	15.0	14.5	14.4	14.1	13.8	13.4	13.2	12.9	12.7	12.4	12.2	*10.4*	*8.1*	*6.4*	*5.1*	*4.1*	CPF8		
17.0	14.2	12.7	11.7	11.0	10.4	10.2	10.0	9.8	9.5	9.4	9.2	9.0	8.8	8.6	*7.8*	*5.2*	*3.8*	CPF8C		
17.0	16.1	15.0	14.5	14.4	14.1	13.8	13.5	13.2	12.9	12.6	12.4	12.1	11.9	*10.3*	*7.8*	*5.2*	*3.8*	CPF8C		
17.0	14.6	13.2	12.1	11.3	10.7	10.4	10.3	10.1	10.0	9.9	9.8	9.7	9.6	9.5	*7.6*	*5.9*	*4.6*	CPF8M		
17.0	17.0	16.5	16.3	15.2	14.4	14.1	13.8	13.6	13.5	13.3	13.2	13.1	*12.6*	*9.8*	*7.6*	*5.9*	*4.6*	CPF8M		
15.8	13.0	12.0	11.5	11.1	10.8	10.5	10.3	10.0	9.7	9.4	9.1	8.7	8.4	*7.2*	*5.5*	*4.3*	*3.2*	CPH8	A 451	
15.8	14.4	13.4	13.1	13.1	13.1	13.0	12.9	12.8	12.5	12.2	11.8	11.3	*9.4*	*7.2*	*5.5*	*4.3*	*3.2*	CPH8		
17.0	13.9	12.8	12.3	11.9	11.5	11.3	11.0	10.7	10.4	10.0	9.7	*7.8*	*5.0*	*3.2*	*2.1*	*1.3*	*0.85*	CPH10		
17.0	15.6	14.5	14.1	14.1	14.1	14.0	13.9	13.8	13.5	13.1	12.7	*7.8*	*5.0*	*3.2*	*2.1*	*1.3*	*0.85*	CPH10		
17.0	13.9	12.8	12.3	11.9	11.5	11.3	11.0	10.7	10.4	10.0	9.7	9.4	9.0	*7.2*	*5.5*	*4.3*	*3.2*	CPH20	A 451	
17.0	15.6	14.5	14.1	14.1	14.1	14.0	13.9	13.8	13.5	13.1	12.7	12.1	*9.4*	*7.2*	*5.5*	*4.3*	*3.2*	CPH20		
15.8	13.0	12.0	11.5	11.1	10.8	10.5	10.3	10.0	9.7	9.4	9.1	8.7	8.4	8.1	*7.2*	*6.2*	*5.1*	CPK20		
15.8	14.4	13.4	13.1	13.1	13.1	13.0	12.9	12.8	12.5	12.2	11.8	11.3	*9.6*	*8.3*	*7.2*	*6.2*	*5.1*	CPK20		
17.0	14.2	12.7	11.7	11.0	10.4	10.2	10.0	9.8	9.6	9.4	9.2	9.0	8.8	8.6	*8.3*	*6.6*	*5.2*	TP304H	A 452	
17.0	17.0	16.1	15.5	14.8	14.1	13.8	13.5	13.2	12.9	12.6	12.4	12.1	11.9	*10.5*	*8.3*	*6.6*	*5.2*	TP304H		
17.0	14.7	13.2	12.1	11.3	10.7	10.5	10.3	10.1	10.0	9.9	9.8	9.7	9.6	9.5	9.4	*8.3*	*6.3*	TP316H		
17.0	17.0	17.0	16.4	15.3	14.5	14.1	13.9	13.7	13.5	13.4	13.2	13.1	13.0	12.9	*10.5*	*8.3*	*6.3*	TP316H		
17.0	15.6	14.6	13.6	12.8	12.2	11.9	11.8	11.6	11.5	11.5	11.4	11.4	11.4	...	...	...	...	TP347H		
17.0	17.0	16.0	15.1	14.6	14.3	14.3	14.3	14.3	14.3	14.3	14.2	14.1	14.0	...	...	...	...	TP347H		
Welded Pipe and Tube – Without Filler Metal Austenitic																				
17.0	14.2	12.7	11.7	11.0	10.4	10.2	10.0	9.8	9.6	9.4	9.2	9.0	8.8	8.6	*8.3*	*6.6*	*5.2*	TP304	A 249	
17.0	17.0	16.1	15.5	14.8	14.1	13.8	13.5	13.2	12.9	12.6	12.4	12.1	11.9	*10.5*	*8.3*	*6.6*	*5.2*	TP304		
17.0	14.2	12.7	11.7	11.0	10.4	10.2	10.0	9.8	9.6	9.4	9.2	9.0	8.8	8.6	*8.3*	*6.6*	*5.2*	TP304H		
17.0	17.0	16.1	15.5	14.8	14.1	13.8	13.5	13.2	12.9	12.6	12.4	12.1	11.9	*10.5*	*8.3*	*6.6*	*5.2*	TP304H		
14.2	12.1	10.9	9.9	9.3	8.8	8.6	8.5	8.3	8.2	...	...	...	...	...	...	...	...	TP304L	A 249	
14.2	14.2	14.2	13.4	12.5	11.9	11.7	11.4	11.3	11.1	...	...	...	...	...	...	...	...	TP304L		
19.4	16.2	14.2	12.8	11.9	11.3	11.0	10.8	10.6	10.5	10.3	10.0	9.8	9.6	9.4	*8.3*	*6.6*	*5.2*	TP304N		
19.4	19.4	18.5	17.3	16.0	15.2	14.9	14.6	14.4	14.1	13.8	13.6	13.3	13.0	*10.5*	*8.3*	*6.6*	*5.2*	TP304N		

Table A-3 Stainless Steels (Cont'd)

Welded Pipe and Tube — Without Filler Metal (Cont'd)
Austenitic (Cont'd)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
A 249	. . .	. . .	S30815	21Cr–11Ni–N	8	(1)	87	45	0.85
	. . .	. . .	S30815	21Cr–11Ni–N	8	(1)(9)	87	45	0.85
A 249	TP309H	. . .	S30909	23Cr–12Ni	8	(9)	75	30	0.85
	TP309H	. . .	S30909	23Cr–12Ni	8	. . .	75	30	0.85
A 249	TP316	. . .	S31600	16Cr–12Ni–2Mo	8	(10)	75	30	0.85
	TP316	. . .	S31600	16Cr–12Ni–2Mo	8	(9)(10)	75	30	0.85
	TP316H	. . .	S31609	16Cr–12Ni–2Mo	8	. . .	75	30	0.85
	TP316H	. . .	S31609	16Cr–12Ni–2Mo	8	(9)	75	30	0.85
A 249	TP316L	. . .	S31603	16Cr–12Ni–2Mo	8	(1)	70	25	0.85
	TP316L	. . .	S31603	16Cr–12Ni–2Mo	8	(1)(9)	70	25	0.85
	TP316N	. . .	S31651	16Cr–12Ni–2Mo–N	8	(10)	80	35	0.85
	TP316N	. . .	S31651	16Cr–12Ni–2Mo–N	8	(9)(10)	80	35	0.85
A 249	TP317	. . .	S31700	18Cr–13Ni–3Mo	8	(1)(10)	75	30	0.85
	TP317	. . .	S31700	18Cr–13Ni–3Mo	8	(1)(9)(10)	75	30	0.85
	TP321	. . .	S32100	18Cr–10Ni–Ti	8	(10)	75	30	0.85
	TP321	. . .	S32100	18Cr–10Ni–Ti	8	(9)(10)	75	30	0.85
	TP321H	. . .	S32109	18Cr–10Ni–Ti	8	. . .	75	30	0.85
	TP321H	. . .	S32109	18Cr–10Ni–Ti	8	(9)	75	30	0.85
A 249	TP347	. . .	S34700	18Cr–10Ni–Cb	8	(10)	75	30	0.85
	TP347	. . .	S34700	18Cr–10Ni–Cb	8	(9)(10)	75	30	0.85
	TP347H	. . .	S34709	18Cr–10Ni–Cb	8	. . .	75	30	0.85
	TP347H	. . .	S34709	18Cr–10Ni–Cb	8	(9)	75	30	0.85
A 249	TP348	. . .	S34800	18Cr–10Ni–Cb	8	(10)	75	30	0.85
	TP348	. . .	S34800	18Cr–10Ni–Cb	8	(9)(10)	75	30	0.85
	TP348H	. . .	S34809	18Cr–10Ni–Cb	8	. . .	75	30	0.85
	TP348H	. . .	S34809	18Cr–10Ni–Cb	8	(9)	75	30	0.85
A 249	. . .	. . .	S31254	20Cr–18Ni–6Mo	8	(1)	94	44	0.85
	. . .	. . .	S31254	20Cr–18Ni–6Mo	8	(1)(9)	94	44	0.85
A 312	TP304	. . .	S30400	18Cr–8Ni	8	(10)	75	30	0.85
	TP304	. . .	S30400	18Cr–8Ni	8	(9)(10)	75	30	0.85
	TP304H	. . .	S30409	18Cr–8Ni	8	. . .	75	30	0.85
	TP304H	. . .	S30409	18Cr–8Ni	8	(9)	75	30	0.85
A 312	TP304L	. . .	S30403	18Cr–8Ni	8	(1)	70	25	0.85
	TP304L	. . .	S30403	18Cr–8Ni	8	(1)(9)	70	25	0.85
	TP304N	. . .	S30451	18Cr–8Ni–N	8	(10)	80	35	0.85
	TP304N	. . .	S30451	18Cr–8Ni–N	8	(9)(10)	80	35	0.85
A 312	. . .	. . .	S30815	21Cr–11Ni–N	8	(1)	87	45	0.85
	. . .	. . .	S30815	21Cr–11Ni–N	8	(1)(9)	87	45	0.85

Table A-3 Stainless Steels (Cont'd)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																			
−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1,000	1,050	1,100	1,150	1,200	Type or Grade	Spec. No.
Welded Pipe and Tube – Without Filler Metal (Cont'd) Austenitic (Cont'd)																			
17.0	17.0	17.0	17.0	16.5	15.9	15.7	15.5	15.3	15.1	14.8	14.6	14.4	*11.7*	*8.8*	*6.5*	*4.7*	*3.4*	TP309H	A 312
17.0	14.9	13.7	12.8	12.2	11.8	11.6	11.5	11.3	11.2	11.0	10.8	10.6	10.4	*8.8*	*6.5*	*4.7*	*3.4*	TP309H	
17.0	17.0	17.0	16.9	16.4	15.7	15.5	15.2	15.0	14.8	14.6	14.4	14.2	*11.7*	*8.8*	*6.5*	*4.7*	*3.4*	TP310H	
17.0	15.0	13.7	12.8	12.1	11.7	11.5	11.3	11.1	11.0	10.8	10.7	10.5	10.3	*8.8*	*6.5*	*4.7*	*3.4*	TP310H	
17.0	14.7	13.2	12.1	11.3	10.7	10.5	10.3	10.1	10.0	9.9	9.8	9.7	9.6	9.5	9.4	*8.3*	*6.3*	TP316	A 312
17.0	17.0	17.0	16.4	15.3	14.5	14.1	13.9	13.7	13.5	13.4	13.2	13.1	13.0	12.9	*10.5*	*8.3*	*6.3*	TP316	
17.0	14.7	13.2	12.1	11.3	10.7	10.5	10.3	10.1	10.0	9.9	9.8	9.7	9.6	9.5	9.4	*8.3*	*6.3*	TP316H	
17.0	17.0	17.0	16.4	15.3	14.5	14.1	13.9	13.7	13.5	13.4	13.2	13.1	13.0	12.9	*10.5*	*8.3*	*6.3*	TP316H	
14.2	12.1	10.8	9.9	9.3	8.8	8.7	8.5	8.3	8.1	8.0	...	...	...	...	...	...	...	TP316L	A 312
14.2	14.2	14.2	13.4	12.5	11.9	11.7	11.4	11.2	11.0	10.8	...	...	...	...	...	...	...	TP316L	
19.4	17.6	16.1	15.0	14.0	13.3	12.9	12.6	12.3	12.1	11.9	11.6	11.4	11.2	11.0	*10.5*	*8.3*	*6.3*	TP316N	
19.4	19.4	18.7	18.2	18.1	17.9	17.4	17.0	16.7	16.3	16.0	15.7	15.4	15.1	*13.4*	*10.5*	*8.3*	*6.3*	TP316N	
17.0	14.7	13.2	12.1	11.3	10.7	10.5	10.3	10.1	10.0	9.9	9.8	9.7	9.6	9.5	9.4	*8.3*	*6.3*	TP317	A 312
17.0	17.0	17.0	16.4	15.3	14.5	14.1	13.9	13.7	13.5	13.4	13.2	13.1	13.0	12.9	*10.5*	*8.3*	*6.3*	TP317	
17.0	15.3	14.1	13.0	12.2	11.5	11.2	11.0	10.8	10.7	10.5	10.4	10.3	10.2	*8.2*	*5.9*	*4.3*	*3.1*	TP321	
17.0	17.0	16.2	15.9	15.9	15.5	15.2	14.9	14.6	14.4	14.2	14.1	13.9	*13.8*	*8.2*	*5.9*	*4.3*	*3.1*	TP321	
17.0	15.3	14.1	13.0	12.2	11.5	11.2	11.0	10.8	10.7	10.5	10.4	10.3	10.2	10.1	*7.7*	*5.9*	*4.6*	TP321H	
17.0	17.0	16.2	15.9	15.9	15.5	15.2	14.9	14.6	14.4	14.2	14.1	13.9	13.8	*10.5*	*7.7*	*5.9*	*4.6*	TP321H	
17.0	15.6	14.6	13.6	12.8	12.2	11.9	11.8	11.6	11.5	11.5	11.4	11.4	11.4	*10.3*	*7.8*	*5.2*	*3.8*	TP347	A 312
17.0	17.0	16.0	15.1	14.6	14.3	14.3	14.3	14.3	14.3	14.3	14.2	14.1	*13.6*	*10.3*	*7.8*	*5.2*	*3.8*	TP347	
17.0	15.6	14.6	13.6	12.8	12.2	11.9	11.8	11.6	11.5	11.5	11.4	11.4	11.4	11.4	11.3	*8.9*	*6.7*	TP347H	
17.0	17.0	16.0	15.1	14.6	14.3	14.3	14.3	14.3	14.3	14.3	14.2	14.1	14.0	13.7	*12.0*	*8.9*	*6.7*	TP347H	
17.0	15.6	14.6	13.6	12.8	12.2	11.9	11.8	11.6	11.5	11.5	11.4	11.4	11.4	*10.3*	*7.8*	*5.2*	*3.8*	TP348	A 312
17.0	17.0	16.0	15.1	14.6	14.3	14.3	14.3	14.3	14.3	14.3	14.2	14.1	*13.6*	*10.3*	*7.8*	*5.2*	*3.8*	TP348	
17.0	15.6	14.6	13.6	12.8	12.2	11.9	11.8	11.6	11.5	11.5	11.4	11.4	11.4	11.4	11.3	*8.9*	*6.7*	TP348H	
17.0	17.0	16.0	15.1	14.6	14.3	14.3	14.3	14.3	14.3	14.3	14.2	14.1	14.0	13.7	*12.0*	*8.9*	*6.7*	TP348H	
17.0	14.2	12.7	11.7	11.0	10.4	10.2	10.0	9.8	9.6	9.4	9.2	9.0	8.8	...	...	...	...	TPXM-15	A 312
17.0	17.0	16.1	15.5	14.8	14.1	13.8	13.5	13.2	12.9	12.6	12.4	12.1	11.9	...	...	...	...	TPXM-15	
22.8	20.3	18.2	16.8	15.8	15.2	15.0	14.8	14.7	...	...	...	...	...	...	...	...	...	...	
22.8	22.8	21.7	20.7	20.0	19.5	19.4	19.3	19.2	...	...	...	...	...	...	...	...	...	...	
21.2	21.0	18.7	16.9	15.7	15.0	14.8	14.6	14.5	14.3	14.1	13.9	13.8	12.7	9.9	7.7	5.9	4.4	...	A 409
21.2	21.0	19.8	19.0	18.5	18.2	18.0	17.9	17.7	17.5	17.3	17.0	16.2	12.7	9.9	7.7	5.9	4.4	...	
26.7	26.6	25.1	24.3	24.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	A 789
26.7	26.6	25.1	24.3	24.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	A 790
Ferritic/Martensitic																			
14.6	14.6	14.3	14.0	13.8	13.5	13.2	12.9	...	...	...	...	...	...	...	...	...	...	TP405	A 268
14.6	14.6	14.3	14.0	13.8	13.5	13.2	12.9	...	...	...	...	...	...	...	...	...	...	TP410	
14.6	14.6	14.3	14.0	13.8	13.5	13.2	12.9	...	...	...	...	...	...	...	...	...	...	TP429	
14.6	14.6	14.3	14.0	13.8	13.5	13.2	12.9	...	...	...	...	...	...	...	...	...	...	TP430	
17.0	17.0	16.4	16.0	15.6	15.2	15.0	14.7	...	...	...	...	...	...	...	...	...	...	TP446-1	
15.8	15.8	15.5	15.4	15.4	15.4	15.4	...	...	...	...	...	...	...	...	...	...	...	TPXM-27	
16.5	16.5	16.4	16.2	16.0	15.7	15.4	...	...	...	...	...	...	...	...	...	...	...	TPXM-33	

Table A-3 Stainless Steels (Cont'd)

	Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
	Welded Pipe and Tube — Without Filler Metal (Cont'd)									
	Ferritic/Martensitic (Cont'd)									
	A 731	TPXM-27	...	S44627	27Cr–1Mo	10I	(2)	65	40	0.85
		TPXM-33	...	S44626	27Cr–1Mo–Ti	10I	(2)	65	40	0.85
	Ferritic/Austenitic									
	A 789	S31803	...	S31803	22Cr–5.5Ni–3Mo–N	10H	(1)(33)(34)	90	65	0.85
(A08)		S32205	...	S32205	22Cr–5.5Ni–3Mo–N	10H	(1)(33)(34)	95	70	0.85
(A08)		S32750	...	S32750	25Cr–7Ni–4Mo–N	10H	(1)(33)(39)	116	80	0.85
	A 790	S31803	...	S31803	22Cr–5.5Ni–3Mo–N	10H	(1)(33)(34)	90	65	0.85
(A08)		S32205	...	S32205	22Cr–5.5Ni–3Mo–N	10H	(1)(33)(34)	90	65	0.85
(A08)		S32750	...	S32750	25Cr–7Ni–4Mo–N	10H	(1)(33)(39)	116	80	0.85
	Welded Pipe — Filler Metal Added									
	Austenitic									
	A 358	304	1 & 3	S30400	18Cr–8Ni	8	(1)(10)(11)	75	30	1.00
		304	2	S30400	18Cr–8Ni	8	(1)(10)(11)	75	30	0.90
		304	1 & 3	S30400	18Cr–8Ni	8	(1)(9)(10)(11)	75	30	1.00
		304	2	S30400	18Cr–8Ni	8	(1)(9)(10)(11)	75	30	0.90
	A 358	304L	1 & 3	S30403	18Cr–8Ni	8	(1)	70	25	1.00
		304L	2	S30403	18Cr–8Ni	8	(1)	70	25	0.90
		304L	1 & 3	S30403	18Cr–8Ni	8	(1)(9)	70	25	1.00
		304L	2	S30403	18Cr–8Ni	8	(1)(9)	70	25	0.90
	A 358	304N	1 & 3	S30451	18Cr–8Ni–N	8	(1)(10)	80	35	1.00
		304N	2	S30451	18Cr–8Ni–N	8	(1)(10)	80	35	0.90
		304N	1 & 3	S30451	18Cr–8Ni–N	8	(1)(9)(10)	80	35	1.00
		304N	2	S30451	18Cr–8Ni–N	8	(1)(9)(10)	80	35	0.90
	A 358	...	1 & 3	S30815	21Cr–11Ni–N	8	(1)	87	45	1.00
		...	2	S30815	21Cr–11Ni–N	8	(1)	87	45	0.90
		...	1 & 3	S30815	21Cr–11Ni–N	8	(1)(9)	87	45	1.00
		...	2	S30815	21Cr–11Ni–N	8	(1)(9)	87	45	0.90
	A 358	309	1 & 3	S30900	23Cr–12Ni	8	(1)(10)	75	30	1.00
		309	2	S30900	23Cr–12Ni	8	(1)(10)	75	30	0.90
		309	1 & 3	S30900	23Cr–12Ni	8	(1)(9)(10)	75	30	1.00
		309	2	S30900	23Cr–12Ni	8	(1)(9)(10)	75	30	0.90
	A 358	310	1 & 3	S31000	25Cr–20Ni	8	(1)(10)(14)	75	30	1.00
		310	2	S31000	25Cr–20Ni	8	(1)(10)(14)	75	30	0.90
		310	1 & 3	S31000	25Cr–20Ni	8	(1)(9)(10)(14)	75	30	1.00
		310	2	S31000	25Cr–20Ni	8	(1)(9)(10)(14)	75	30	0.90
	A 358	310	1 & 3	S31000	25Cr–20Ni	8	(1)(10)(15)	75	30	1.00
		310	2	S31000	25Cr–20Ni	8	(1)(10)(15)	75	30	0.90
		310	1 & 3	S31000	25Cr–20Ni	8	(1)(9)(10)(15)	75	30	1.00
		310	2	S31000	25Cr–20Ni	8	(1)(9)(10)(15)	75	30	0.90
	A 358	316	1 & 3	S31600	16Cr–12Ni–2Mo	8	(1)(10)(11)	75	30	1.00
		316	2	S31600	16Cr–12Ni–2Mo	8	(1)(10)(11)	75	30	0.90
		316	1 & 3	S31600	16Cr–12Ni–2Mo	8	(1)(9)(10)(11)	75	30	1.00
		316	2	S31600	16Cr–12Ni–2Mo	8	(1)(9)(10)(11)	75	30	0.90

Table A-3 Stainless Steels (Cont'd)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																				
−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1,000	1,050	1,100	1,150	1,200	Type or Grade	Spec. No.	
Welded Pipe and Tube – Without Filler Metal (Cont'd) Ferritic/Martensitic (Cont'd)																				
15.8	15.8	15.5	15.4	15.4	15.4	15.4	...	...	...	...	...	...	...	...	...	...	...	TPXM-27	A 731	
15.8	15.8	15.7	15.4	15.3	15.0	14.7	...	...	...	...	...	...	...	...	...	...	...	TPXM-33		
Ferritic/Austenitic																				
21.9	21.9	21.1	20.3	19.8	19.6	...	...	...	...	...	...	...	...	...	...	...	...	S31803	A 789	
23.1	23.1	22.3	21.4	20.9	20.7	...	...	...	...	...	...	...	...	...	...	...	...	S32205		**(A08)**
28.2	28.0	26.5	25.6	25.2	25.0	...	...	...	...	...	...	...	...	...	...	...	...	S32750		**(A08)**
21.9	21.9	21.1	20.3	19.8	19.6	...	...	...	...	...	...	...	...	...	...	...	...	S31803	A 790	
21.9	21.9	21.1	20.3	19.8	19.6	...	...	...	...	...	...	...	...	...	...	...	...	S32205		**(A08)**
28.2	28.0	26.5	25.6	25.2	25.0	...	...	...	...	...	...	...	...	...	...	...	...	S32750		**(A08)**
Welded Pipe – Filler Metal Added Austenitic																				
20.0	16.7	15.0	13.8	12.9	12.3	12.0	11.7	11.5	11.2	11.0	10.8	10.6	10.4	10.1	*9.8*	*7.7*	*6.1*	304	A 358	
18.0	15.0	13.5	12.4	11.6	11.1	10.8	10.6	10.3	10.1	9.9	9.7	9.5	9.3	9.1	*8.8*	*7.0*	*5.5*	304		
20.0	20.0	18.9	18.3	17.5	16.6	16.2	15.8	15.5	15.2	14.9	14.6	14.3	14.0	*12.4*	*9.8*	*7.7*	*6.1*	304		
16.2	16.2	15.3	14.8	14.1	13.4	13.1	12.8	12.6	12.3	12.0	11.8	11.6	11.3	*10.0*	*7.9*	*6.3*	*4.9*	304		
16.7	14.3	12.8	11.7	10.9	10.4	10.2	10.0	9.8	9.7	...	...	...	...	...	...	...	...	304L	A 358	
15.0	12.8	11.5	10.5	9.8	9.3	9.1	9.0	8.8	8.7	...	...	...	...	...	...	...	...	304L		
16.7	16.7	16.7	15.8	14.7	14.0	13.7	13.5	13.3	13.0	...	...	...	...	...	...	...	...	304L		
15.0	15.0	15.0	14.2	13.3	12.6	12.3	12.1	11.9	11.7	...	...	...	...	...	...	...	...	304L		
22.9	19.1	16.7	15.1	14.0	13.3	13.0	12.8	12.5	12.3	12.1	11.8	11.6	11.3	11.0	*9.8*	*7.7*	*6.1*	304N	A 358	
20.6	17.2	15.0	13.5	12.6	11.9	11.7	11.5	11.3	11.1	10.9	10.6	10.4	10.2	9.9	*8.8*	*7.0*	*5.5*	304N		
22.9	22.9	21.7	20.3	18.9	17.9	17.5	17.2	16.9	16.6	16.3	16.0	15.6	15.2	*12.4*	*9.8*	*7.7*	*6.1*	304N		
20.6	20.6	19.6	18.3	17.0	16.1	15.8	15.5	15.2	14.9	14.7	14.4	14.0	13.7	*11.2*	*8.8*	*7.0*	*5.5*	304N		
24.9	24.7	22.0	19.9	18.5	17.7	17.4	17.2	17.0	16.8	16.6	16.4	16.2	14.9	11.6	9.0	6.9	5.2	...	A 358	
22.4	22.2	21.0	20.2	19.6	19.3	19.1	18.9	18.7	18.5	18.3	18.0	17.2	13.4	10.4	8.1	6.2	4.7	...		
24.9	24.7	22.0	19.9	18.5	17.7	17.4	17.2	17.0	16.8	16.6	16.4	16.2	14.9	11.6	9.0	6.9	5.2	...		
22.4	22.2	21.0	20.2	19.6	19.3	19.1	18.9	18.7	18.5	18.3	18.0	17.2	13.4	10.4	8.1	6.2	4.7	...		
20.0	17.5	16.1	15.1	14.4	13.9	13.7	13.5	13.3	13.1	12.9	12.7	12.5	*9.9*	*7.1*	*5.0*	*3.6*	*2.5*	309	A 358	
18.0	15.8	14.5	13.6	13.0	12.5	12.3	12.1	12.0	11.8	11.6	11.5	11.3	*8.9*	*6.4*	*4.5*	*3.2*	*2.3*	309		
20.0	20.0	20.0	20.0	19.4	18.8	18.5	18.2	18.0	17.7	17.5	17.2	*15.9*	*9.9*	*7.1*	*5.0*	*3.6*	*2.5*	309		
18.0	18.0	18.0	18.0	17.5	16.9	16.6	16.4	16.2	15.9	15.7	15.5	*14.3*	*8.9*	*6.4*	*4.5*	*3.2*	*2.3*	309		
20.0	17.6	16.1	15.1	14.3	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.3	*9.9*	*7.1*	*5.0*	*3.6*	*2.5*	310	A 358	
18.0	15.9	14.5	13.6	12.9	12.4	12.1	12.0	11.8	11.6	11.5	11.3	11.1	*8.9*	*6.4*	*4.5*	*3.2*	*2.3*	310		
20.0	20.0	20.0	19.9	19.3	18.5	18.2	17.9	17.7	17.4	17.2	16.9	*15.9*	*9.9*	*7.1*	*5.0*	*3.6*	*2.5*	310		
18.0	18.0	18.0	17.9	17.4	16.7	16.4	16.1	15.9	15.7	15.5	15.2	*14.3*	*8.9*	*6.4*	*4.5*	*3.2*	*2.3*	310		
20.0	17.6	16.1	15.1	14.3	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.3	*9.9*	*7.1*	*5.0*	*3.6*	*2.5*	310	A 358	
18.0	15.9	14.5	13.6	12.9	12.4	12.1	12.0	11.8	11.6	11.5	11.3	11.1	*8.9*	*6.4*	*4.5*	*3.2*	*2.3*	310		
20.0	20.0	20.0	19.9	19.3	18.5	18.2	17.9	17.7	17.4	17.2	16.9	*15.9*	*9.9*	*7.1*	*5.0*	*3.6*	*2.5*	310		
18.0	18.0	18.0	17.9	17.4	16.7	16.4	16.1	15.9	15.7	15.5	15.2	*14.3*	*8.9*	*6.4*	*4.5*	*3.2*	*2.3*	310		
20.0	17.3	15.6	14.3	13.3	12.6	12.3	12.1	11.9	11.8	11.6	11.5	11.4	11.3	11.2	11.1	*9.8*	*7.4*	316	A 358	
18.0	15.5	14.0	12.9	12.0	11.3	11.1	10.9	10.7	10.6	10.5	10.4	10.3	10.2	10.1	9.9	*8.8*	*6.7*	316		
20.0	20.0	20.0	19.3	18.0	17.0	16.6	16.3	16.1	15.9	15.7	15.6	15.4	15.3	15.1	*12.4*	*9.8*	*7.4*	316		
18.0	18.0	18.0	17.4	16.2	15.3	15.0	14.7	14.5	14.3	14.1	14.0	13.9	13.8	13.6	*11.2*	*8.8*	*6.7*	316		

Table A-3 Stainless Steels (Cont'd)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
Welded Pipe — Filler Metal Added (Cont'd)									
Austenitic (Cont'd)									
A 358	316L	1 & 3	S31603	16Cr–12Ni–2Mo	8	(1)	70	25	1.00
	316L	2	S31603	16Cr–12Ni–2Mo	8	(1)	70	25	0.90
	316L	1 & 3	S31603	16Cr–12Ni–2Mo	8	(1)(9)	70	25	1.00
	316L	2	S31603	16Cr–12Ni–2Mo	8	(1)(9)	70	25	0.90
A 358	316N	1 & 3	S31651	16Cr–12Ni–2Mo–N	8	(1)(10)	80	35	1.00
	316N	2	S31651	16Cr–12Ni–2Mo–N	8	(1)(10)	80	35	0.90
	316N	1 & 3	S31651	16Cr–12Ni–2Mo–N	8	(1)(9)(10)	80	35	1.00
	316N	2	S31651	16Cr–12Ni–2Mo–N	8	(1)(9)(10)	80	35	0.90
A 358	321	1 & 3	S32100	18Cr–10Ni–Ti	8	(1)(10)(11)	75	30	1.00
	321	2	S32100	18Cr–10Ni–Ti	8	(1)(10)(11)	75	30	0.90
	321	1 & 3	S32100	18Cr–10Ni–Ti	8	(1)(9)(10)(11)	75	30	1.00
	321	2	S32100	18Cr–10Ni–Ti	8	(1)(9)(10)(11)	75	30	0.90
A 358	347	1 & 3	S34700	18Cr–10Ni–Cb	8	(1)(10)(11)	75	30	1.00
	347	2	S34700	18Cr–10Ni–Cb	8	(1)(10)(11)	75	30	0.90
	347	1 & 3	S34700	18Cr–10Ni–Cb	8	(1)(9)(10)(11)	75	30	1.00
	347	2	S34700	18Cr–10Ni–Cb	8	(1)(9)(10)(11)	75	30	0.90
A 358	348	1 & 3	S34800	18Cr–10Ni–Cb	8	(1)(10)(11)	75	30	1.00
	348	2	S34800	18Cr–10Ni–Cb	8	(1)(10)(11)	75	30	0.90
	348	1 & 3	S34800	18Cr–10Ni–Cb	8	(1)(9)(10)(11)	75	30	1.00
	348	2	S34800	18Cr–10Ni–Cb	8	(1)(9)(10)(11)	75	30	0.90
A 358	. . .	1 & 3	S31254	20Cr–18Ni–6Mo	8	(1)	94	44	1.00
	. . .	2	S31254	20Cr–18Ni–6Mo	8	(1)	94	44	0.90
	. . .	1 & 3	S31254	20Cr–18Ni–6Mo	8	(1)(9)	94	44	1.00
	. . .	2	S31254	20Cr–18Ni–6Mo	8	(1)(9)	94	44	0.90
A 409	TP304	. . .	S30400	18Cr–8Ni	8	(1)(10)(29)	75	30	1.00
	TP304	. . .	S30400	18Cr–8Ni	8	(1)(10)(30)	75	30	0.90
	TP304	. . .	S30400	18Cr–8Ni	8	(1)(10)(31)	75	30	0.80
	TP304	. . .	S30400	18Cr–8Ni	8	(1)(9)(10)(29)	75	30	1.00
	TP304	. . .	S30400	18Cr–8Ni	8	(1)(9)(10)(30)	75	30	0.90
	TP304	. . .	S30400	18Cr–8Ni	8	(1)(9)(10)(31)	75	30	0.80
A 409	TP304L	. . .	S30403	18Cr–8Ni	8	(1)(29)	70	25	1.00
	TP304L	. . .	S30403	18Cr–8Ni	8	(1)(30)	70	25	0.90
	TP304L	. . .	S30403	18Cr–8Ni	8	(1)(31)	70	25	0.80
	TP304L	. . .	S30403	18Cr–8Ni	8	(1)(9)(29)	70	25	1.00
	TP304L	. . .	S30403	18Cr–8Ni	8	(1)(9)(30)	70	25	0.90
	TP304L	. . .	S30403	18Cr–8Ni	8	(1)(9)(31)	70	25	0.80
A 409	. . .	. . .	S30815	21Cr–11Ni–N	8	(1)(29)	87	45	1.00
	. . .	. . .	S30815	21Cr–11Ni–N	8	(1)(30)	87	45	0.90
	. . .	. . .	S30815	21Cr–11Ni–N	8	(1)(31)	87	45	0.80
	. . .	. . .	S30815	21Cr–11Ni–N	8	(1)(9)(29)	87	45	1.00
	. . .	. . .	S30815	21Cr–11Ni–N	8	(1)(9)(30)	87	45	0.90
	. . .	. . .	S30815	21Cr–11Ni–N	8	(1)(9)(31)	87	45	0.80

Table A-3 Stainless Steels (Cont'd)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																			
−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1,000	1,050	1,100	1,150	1,200	Type or Grade	Spec. No.
Welded Pipe – Filler Metal Added (Cont'd) Austenitic (Cont'd)																			
20.0	17.3	15.6	14.3	13.3	12.6	12.3	12.1	11.9	11.8	11.6	11.5	11.4	11.3	11.2	11.1	*9.8*	*7.4*	TP316	A 409
18.0	15.5	14.0	12.9	12.0	11.3	11.1	10.9	10.7	10.6	10.5	10.4	10.3	10.2	10.1	9.9	*8.8*	*6.7*	TP316	
16.0	13.8	12.5	11.4	10.6	10.1	9.9	9.7	9.5	9.4	9.3	9.2	9.1	9.1	9.0	8.8	*7.8*	*5.9*	TP316	
20.0	20.0	20.0	19.3	18.0	17.0	16.6	16.3	16.1	15.9	15.7	15.6	15.4	15.3	15.1	*12.4*	*9.8*	*7.4*	TP316	
18.0	18.0	18.0	17.4	16.2	15.3	15.0	14.7	14.5	14.3	14.1	14.0	13.9	13.8	13.6	11.2	8.8	6.7	TP316	
16.0	16.0	16.0	15.4	14.4	13.6	13.3	13.1	12.9	12.7	12.6	12.5	12.3	12.2	12.1	9.9	7.8	5.9	TP316	
16.7	14.2	12.7	11.7	10.9	10.4	10.2	10.0	9.8	9.6	9.4	...	...	...	...	...	...	...	TP316L	A 409
15.0	12.8	11.4	10.5	9.8	9.4	9.2	9.0	8.8	8.6	8.4	...	...	...	...	...	...	...	TP316L	
13.3	11.4	10.2	9.3	8.7	8.3	8.1	8.0	7.8	7.7	7.5	...	...	...	...	...	...	...	TP316L	
16.7	16.7	16.7	15.7	14.8	14.0	13.7	13.5	13.2	12.9	12.7	...	...	...	...	...	...	...	TP316L	
15.0	15.0	15.0	14.2	13.3	12.6	12.4	12.1	11.9	11.6	11.4	...	...	...	...	...	...	...	TP316L	
13.3	13.3	13.3	12.6	11.8	11.2	11.0	10.8	10.6	10.3	10.1	...	...	...	...	...	...	...	TP316L	
Ferritic/Austenitic																			
25.7	25.7	24.8	23.9	23.3	23.1	...	...	...	...	...	...	...	...	...	...	...	...	S31803	A 928
23.1	23.1	22.3	21.5	21.0	20.8	...	...	...	...	...	...	...	...	...	...	...	...	S31803	
Plate, Sheet, and Strip Austenitic																			
20.0	16.7	15.0	13.8	12.9	12.3	12.0	11.7	11.5	11.2	11.0	10.8	10.6	10.4	10.1	*9.8*	*7.7*	*6.1*	304	A 240
20.0	20.0	18.9	18.3	17.5	16.6	16.2	15.8	15.5	15.2	14.9	14.6	14.3	14.0	*12.4*	*9.8*	*7.7*	*6.1*	304	
16.7	14.3	12.8	11.7	10.9	10.4	10.2	10.0	9.8	9.7	...	...	...	...	...	...	...	...	304L	
16.7	16.7	16.7	15.8	14.7	14.0	13.7	13.5	13.3	13.0	...	...	...	...	...	...	...	...	304L	
22.9	19.1	16.7	15.1	14.0	13.3	13.0	12.8	12.5	12.3	12.1	11.8	11.6	11.3	11.0	*9.8*	*7.7*	*6.1*	304N	
22.9	22.9	21.7	20.3	18.9	17.9	17.5	17.2	16.9	16.6	16.3	16.0	15.6	15.2	*12.4*	*9.8*	*7.7*	*6.1*	304N	
24.9	24.7	22.0	19.9	18.5	17.7	17.4	17.2	17.0	16.8	16.6	16.4	16.2	14.9	11.6	9.0	6.9	5.2	...	A 240
24.9	24.7	23.3	22.4	21.8	21.4	21.2	21.0	20.8	20.6	20.3	20.0	19.1	14.9	11.6	9.0	6.9	5.2	...	
20.0	20.0	20.0	20.0	19.4	18.8	18.5	18.2	18.0	17.7	17.5	17.2	16.9	*13.8*	*10.3*	*7.6*	*5.5*	*4.0*	309H	A 240
20.0	17.5	16.1	15.1	14.4	13.9	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.3	*10.3*	*7.6*	*5.5*	*4.0*	309H	
20.0	17.5	16.1	15.1	14.4	13.9	13.7	13.5	13.3	13.1	12.9	12.7	12.5	*9.9*	*7.1*	*5.0*	*3.6*	*2.5*	309S	
20.0	20.0	20.0	20.0	19.4	18.8	18.5	18.2	18.0	17.7	17.5	17.2	*15.9*	*9.9*	*7.1*	*5.0*	*3.6*	*2.5*	309S	
20.0	20.0	20.0	19.9	19.3	18.5	18.2	17.9	17.7	17.4	17.2	16.9	16.7	*13.8*	*10.3*	*7.6*	*5.5*	*4.0*	310H	A 240
20.0	17.6	16.1	15.1	14.3	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.3	12.1	*10.3*	*7.6*	*5.5*	*4.0*	310H	
20.0	17.6	16.1	15.1	14.3	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.3	*9.9*	*7.1*	*5.0*	*3.6*	*2.5*	310S	
20.0	20.0	20.0	19.9	19.3	18.5	18.2	17.9	17.7	17.4	17.2	16.9	*15.9*	*9.9*	*7.1*	*5.0*	*3.6*	*2.5*	310S	
20.0	17.6	16.1	15.1	14.3	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.3	*9.9*	*7.1*	*5.0*	*3.6*	*2.5*	310S	
20.0	20.0	20.0	19.9	19.3	18.5	18.2	17.9	17.7	17.4	17.2	16.9	*15.9*	*9.9*	*7.1*	*5.0*	*3.6*	*2.5*	310S	
20.0	17.3	15.6	14.3	13.3	12.6	12.3	12.1	11.9	11.8	11.6	11.5	11.4	11.3	11.2	11.1	*9.8*	*7.4*	316	A 240
20.0	20.0	20.0	19.3	18.0	17.0	16.6	16.3	16.1	15.9	15.7	15.6	15.4	15.3	15.1	*12.4*	*9.8*	*7.4*	316	
16.7	14.2	12.7	11.7	10.9	10.4	10.2	10.0	9.8	9.6	9.4	9.2	9.0	8.8	8.6	8.4	8.3	*6.4*	316L	
16.7	16.7	16.7	15.7	14.8	14.0	13.7	13.5	13.2	12.9	12.7	12.4	12.1	11.8	*10.8*	*10.2*	*8.8*	*6.4*	316L	
22.9	20.7	19.0	17.6	16.5	15.6	15.2	14.9	14.5	14.2	13.9	13.7	13.4	13.2	12.9	*12.3*	*9.8*	*7.4*	316N	
22.9	22.9	22.0	21.5	21.2	21.0	20.5	20.0	19.6	19.2	18.8	18.5	18.1	17.8	*15.8*	*12.3*	*9.8*	*7.4*	316N	

Table A-3 Stainless Steels (Cont'd)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
Plate, Sheet, and Strip (Cont'd)									
Austenitic (Cont'd)									
A 240	317	...	S31700	18Cr–13Ni–3Mo	8	(1)(10)(11)	75	30	1.00
	317	...	S31700	18Cr–13Ni–3Mo	8	(1)(9)(10)(11)	75	30	1.00
	317L	...	S31703	18Cr–13Ni–3Mo	8	(1)	75	30	1.00
	317L	...	S31703	18Cr–13Ni–3Mo	8	(1)(9)	75	30	1.00
	321	...	S32100	18Cr–10Ni–Ti	8	(10)(11)	75	30	1.00
	321	...	S32100	18Cr–10Ni–Ti	8	(9)(10)(11)	75	30	1.00
A 240	347	...	S34700	18Cr–10Ni–Cb	8	(10)(11)	75	30	1.00
	347	...	S34700	18Cr–10Ni–Cb	8	(9)(10)(11)	75	30	1.00
	348	...	S34800	18Cr–10Ni–Cb	8	(1)(10)(11)	75	30	1.00
	348	...	S34800	18Cr–10Ni–Cb	8	(1)(9)(10)(11)	75	30	1.00
A 240	XM-15	...	S38100	18Cr–8Ni–2Si	8	(1)	75	30	1.00
	XM-15	...	S38100	18Cr–8Ni–2Si	8	(1)(9)	75	30	1.00
	...	...	S31254	20Cr–18Ni–6Mo	8	(1)	94	44	1.00
	...	...	S31254	20Cr–18Ni–6Mo	8	(1)(9)	94	44	1.00
	...	...	S32550	25.5Cr–5.5Ni–3.5Mo–2Cu	10H	(1)(35)(36)	110	80	1.00
Ferritic/Martensitic									
A 240	405	...	S40500	12Cr–1Al	7	(3)	60	25	1.00
	410	...	S41000	13Cr	6	(1)	65	30	1.00
	410S	...	S41008	13Cr	7	(1)	60	30	1.00
	429	...	S42900	15Cr	6	(1)(3)	65	30	1.00
A 240	430	...	S43000	17Cr	7	(1)(3)	65	30	1.00
	XM-27	...	S44627	26Cr–1Mo	10I	(1)(3)	65	40	1.00
	XM-33	...	S44626	27Cr–1Mo–Ti	10I	(2)	68	45	1.00
Ferritic/Austenitic									
A 240	S31803	...	S31803	22Cr–5.5Ni–3Mo–N	10H	(1)(33)(34)	90	65	1.00
(A08)	S32205	...	S32205	22Cr–5.5Ni–3Mo–N	10H	(1)(33)(34)	90	65	1.00
(A08)	S32750	...	S32750	25Cr–7Ni–4Mo–N	10H	(1)(33)(39)	116	80	1.00
Forgings									
Austenitic									
A 182	F44	...	S31254	20Cr–18Ni–6Mo	8	(1)	94	44	1.00
	F44	...	S31254	20Cr–18Ni–6Mo	8	(1)(9)	94	44	1.00
A 182	F304	...	S30400	18Cr–8Ni	8	(10)(12)	70	30	1.00
	F304	...	S30400	18Cr–8Ni	8	(9)(10)(12)	70	30	1.00
	F304	...	S30400	18Cr–8Ni	8	(10)	75	30	1.00
	F304	...	S30400	18Cr–8Ni	8	(9)(10)	75	30	1.00
A 182	F304H	...	S30409	18Cr–8Ni	8	(12)	70	30	1.00
	F304H	...	S30409	18Cr–8Ni	8	(9)(12)	70	30	1.00
	F304H	...	S30409	18Cr–8Ni	8	...	75	30	1.00
	F304H	...	S30409	18Cr–8Ni	8	(9)	75	30	1.00
A 182	F304L	...	S30403	18Cr–8Ni	8	(1)	65	25	1.00
	F304L	...	S30403	18Cr–8Ni	8	(1)(9)	65	25	1.00
	F304N	...	S30451	18Cr–8Ni–N	8	(10)	80	35	1.00
	F304N	...	S30451	18Cr–8Ni–N	8	(9)(10)	80	35	1.00

Table A-3 Stainless Steels (Cont'd)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																				
−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1,000	1,050	1,100	1,150	1,200	Type or Grade	Spec. No.	
																		Plate, Sheet, and Strip (Cont'd) Austenitic (Cont'd)		
20.0	17.3	15.6	14.3	13.3	12.6	12.3	12.1	11.9	11.8	11.6	11.5	11.4	11.3	11.2	11.1	*9.8*	*7.4*	317	A 240	
20.0	20.0	20.0	19.3	18.0	17.0	16.6	16.3	16.1	15.9	15.7	15.6	15.4	15.3	15.1	*12.4*	*9.8*	*7.4*	317		
20.0	17.0	15.2	14.0	13.1	12.5	12.2	12.0	11.7	11.5	11.3	...	...	...	...	...	...	...	317L		
20.0	20.0	19.6	18.9	17.7	16.9	16.5	16.2	15.8	15.5	15.2	...	...	...	...	...	...	...	317L		
20.0	18.0	16.5	15.3	14.3	13.5	13.2	13.0	12.7	12.6	12.4	12.3	12.1	12.0	*9.6*	*6.9*	*5.0*	*3.6*	321		
20.0	20.0	19.1	18.7	18.7	18.3	17.9	17.5	17.2	16.9	16.7	16.5	16.4	*16.2*	*9.6*	*6.9*	*5.0*	*3.6*	321		
20.0	18.4	17.1	16.0	15.0	14.3	14.0	13.8	13.7	13.6	13.5	13.4	13.4	13.4	*12.1*	*9.1*	*6.1*	*4.4*	347	A 240	
20.0	20.0	18.8	17.8	17.2	16.9	16.8	16.8	16.8	16.8	16.8	16.7	16.6	*16.0*	*12.1*	*9.1*	*6.1*	*4.4*	347		
20.0	18.4	17.1	16.0	15.0	14.3	14.0	13.8	13.7	13.6	13.5	13.4	13.4	13.4	*12.1*	*9.1*	*6.1*	*4.4*	348		
20.0	20.0	18.8	17.8	17.2	16.9	16.8	16.8	16.8	16.8	16.8	16.7	16.6	*16.0*	*12.1*	*9.1*	*6.1*	*4.4*	348		
20.0	16.7	15.0	13.8	12.9	12.3	12.0	11.7	11.5	11.2	11.0	10.8	10.6	10.4	...	...	...	...	XM-15	A 240	
20.0	20.0	18.9	18.3	17.5	16.6	16.2	15.8	15.5	15.2	14.9	14.6	14.3	14.0	...	...	...	...	XM-15		
26.9	23.9	21.4	19.8	18.6	17.9	17.6	17.4	17.3	...	...	...	...	...	...	...	...	...	...		
26.9	26.9	25.5	24.3	23.5	23.0	22.8	22.7	22.6	...	...	...	...	...	...	...	...	...	...		
31.4	31.3	29.5	28.6	28.2	...	...	...	...	...	...	...	...	...	...	...	...	...	...		
																		Ferritic/Martensitic		
16.7	15.3	14.8	14.5	14.3	14.0	13.8	13.5	...	...	...	...	...	...	...	...	...	...	405	A 240	
18.6	18.4	17.8	17.4	17.2	16.8	16.6	16.2	15.7	15.1	14.4	*12.3*	*8.8*	*6.4*	*4.4*	*2.9*	*1.8*	*1.0*	410		
17.1	17.1	16.8	16.5	16.3	15.9	15.6	15.2	14.7	14.1	13.4	*12.3*	*8.8*	*6.4*	*4.4*	*2.9*	*1.8*	*1.0*	410S		
18.6	18.4	17.8	17.4	17.2	16.8	16.6	16.2	15.7	15.1	14.4	*12.0*	*9.2*	*6.5*	*4.5*	*3.2*	*2.4*	*1.8*	429		
18.6	18.4	17.8	17.4	17.2	16.8	16.6	16.2	15.7	15.1	14.4	*12.0*	*9.2*	*6.5*	*4.5*	*3.2*	*2.4*	*1.8*	430	A 240	
18.6	18.6	18.3	18.1	18.1	18.1	18.1	...	...	...	...	...	...	...	...	...	...	...	XM-27		
19.4	19.4	19.3	19.0	18.8	18.4	18.1	...	...	...	...	...	...	...	...	...	...	...	XM-33		
																		Ferritic/Austenitic		
25.7	25.7	24.8	23.9	23.3	23.1	...	...	...	...	...	...	...	...	...	...	...	...	S31803	A 240	
25.7	25.7	24.8	23.9	23.3	23.1	...	...	...	...	...	...	...	...	...	...	...	...	S32205		**(A08)**
33.1	33.0	31.2	30.1	29.6	29.4	...	...	...	...	...	...	...	...	...	...	...	...	S32750		**(A08)**
																		Forgings Austenitic		
26.9	23.9	21.4	19.8	18.6	17.9	17.6	17.4	17.3	...	...	...	...	...	...	...	...	...	F44	A 182	
26.9	26.9	25.5	24.3	23.5	23.0	22.8	22.7	22.6	...	...	...	...	...	...	...	...	...	F44		
20.0	16.7	15.0	13.8	12.9	12.3	12.0	11.7	11.5	11.2	11.0	10.8	10.6	10.4	10.1	*9.8*	*7.7*	*6.1*	F304	A 182	
20.0	20.0	18.9	18.3	17.5	16.6	16.2	15.8	15.5	15.2	14.9	14.6	14.3	14.0	*12.4*	*9.8*	*7.7*	*6.1*	F304		
20.0	16.7	15.0	13.8	12.9	12.3	12.0	11.7	11.5	11.2	11.0	10.8	10.6	10.4	10.1	*9.8*	*7.7*	*6.1*	F304		
20.0	20.0	18.9	18.3	17.5	16.6	16.2	15.8	15.5	15.2	14.9	14.6	14.3	14.0	*12.4*	*9.8*	*7.7*	*6.1*	F304		
20.0	16.7	15.0	13.8	12.9	12.3	12.0	11.7	11.5	11.2	11.0	10.8	10.6	10.4	10.1	*9.8*	*7.7*	*6.1*	F304H	A 182	
20.0	18.9	17.7	17.1	16.9	16.6	16.2	15.8	15.5	15.2	14.9	14.6	14.3	14.0	*12.4*	*9.8*	*7.7*	*6.1*	F304H		
20.0	16.7	15.0	13.8	12.9	12.3	12.0	11.7	11.5	11.2	11.0	10.8	10.6	10.4	10.1	*9.8*	*7.7*	*6.1*	F304H		
20.0	20.0	18.9	18.3	17.5	16.6	16.2	15.8	15.5	15.2	14.9	14.6	14.3	14.0	*12.4*	*9.8*	*7.7*	*6.1*	F304H		
16.7	14.3	12.8	11.7	10.9	10.4	10.2	10.0	9.8	9.7	...	...	...	...	...	...	...	...	F304L	A 182	
16.7	16.7	16.2	15.6	14.7	14.0	13.7	13.5	13.3	13.0	...	...	...	...	...	...	...	...	F304L		
22.9	19.1	16.7	15.1	14.0	13.3	13.0	12.8	12.5	12.3	12.1	11.8	11.6	11.3	11.0	*9.8*	*7.7*	*6.1*	F304N		
22.9	22.9	21.7	20.3	18.9	17.9	17.5	17.2	16.9	16.6	16.3	16.0	15.6	15.2	*12.4*	*9.8*	*7.7*	*6.1*	F304N		

Table A-3 Stainless Steels (Cont'd)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
Forgings (Cont'd)									
Austenitic (Cont'd)									
A 182	...	...	S30815	21Cr–11Ni–N	8	(1)	87	45	1.00
	...	...	S30815	21Cr–11Ni–N	8	(1)(9)	87	45	1.00
A 182	F310	...	S31000	25Cr–20Ni	8	(1)(10)(14)	75	30	1.00
	F310	...	S31000	25Cr–20Ni	8	(1)(9)(10)(14)	75	30	1.00
	F310	...	S31000	25Cr–20Ni	8	(1)(10)(15)	75	30	1.00
	F310	...	S31000	25Cr–20Ni	8	(1)(9)(10)(15)	75	30	1.00
A 182	F316	...	S31600	16Cr–12Ni–2Mo	8	(10)(12)	70	30	1.00
	F316	...	S31600	16Cr–12Ni–2Mo	8	(9)(10)(12)	70	30	1.00
	F316	...	S31600	16Cr–12Ni–2Mo	8	(10)	75	30	1.00
	F316	...	S31600	16Cr–12Ni–2Mo	8	(9)(10)	75	30	1.00
A 182	F316H	...	S31609	16Cr–12Ni–2Mo	8	(12)	70	30	1.00
	F316H	...	S31609	16Cr–12Ni–2Mo	8	(9)(12)	70	30	1.00
	F316H	...	S31609	16Cr–12Ni–2Mo	8	...	75	30	1.00
	F316H	...	S31609	16Cr–12Ni–2Mo	8	(9)	75	30	1.00
A 182	F316L	...	S31603	16Cr–12Ni–2Mo	8	(1)(37)	70	25	1.00
	F316L	...	S31603	16Cr–12Ni–2Mo	8	(1)(9)(37)	70	25	1.00
	F316N	...	S31651	16Cr–12Ni–2Mo–N	8	(10)	80	35	1.00
	F316N	...	S31651	16Cr–12Ni–2Mo–N	8	(9)(10)	80	35	1.00
A 182	F321	...	S32100	18Cr–10Ni–Ti	8	(12)	70	30	1.00
	F321	...	S32100	18Cr–10Ni–Ti	8	(9)(12)	70	30	1.00
	F321	...	S32100	18Cr–10Ni–Ti	8	(10)	75	30	1.00
	F321	...	S32100	18Cr–10Ni–Ti	8	(9)(10)	75	30	1.00
A 182	F321H	...	S32109	18Cr–10Ni–Ti	8	(12)	70	30	1.00
	F321H	...	S32109	18Cr–10Ni–Ti	8	(9)(12)	70	30	1.00
	F321H	...	S32109	18Cr–10Ni–Ti	8	...	75	30	1.00
	F321H	...	S32109	18Cr–10Ni–Ti	8	(9)	75	30	1.00
A 182	F347	...	S34700	18Cr–10Ni–Cb	8	(12)	70	30	1.00
	F347	...	S34700	18Cr–10Ni–Cb	8	(9)(12)	70	30	1.00
	F347	...	S34700	18Cr–10Ni–Cb	8	(10)	75	30	1.00
	F347	...	S34700	18Cr–10Ni–Cb	8	(9)(10)	75	30	1.00
A 182	F347H	...	S34709	18Cr–10Ni–Cb	8	(12)	70	30	1.00
	F347H	...	S34709	18Cr–10Ni–Cb	8	(9)(12)	70	30	1.00
	F347H	...	S34709	18Cr–10Ni–Cb	8	...	75	30	1.00
	F347H	...	S34709	18Cr–10Ni–Cb	8	(9)	75	30	1.00
A 182	F348	...	S34800	18Cr–10Ni–Cb	8	(12)	70	30	1.00
	F348	...	S34800	18Cr–10Ni–Cb	8	(9)(12)	70	30	1.00
	F348	...	S34800	18Cr–10Ni–Cb	8	(10)	75	30	1.00
	F348	...	S34800	18Cr–10Ni–Cb	8	(9)(10)	75	30	1.00

Table A-3 Stainless Steels (Cont'd)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																			
−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1,000	1,050	1,100	1,150	1,200	Type or Grade	Spec. No.
																		Forgings (Cont'd) Austenitic (Cont'd)	
24.9	24.7	22.0	19.9	18.5	17.7	17.4	17.2	17.0	16.8	16.6	16.4	16.2	14.9	11.6	9.0	6.9	5.2	. . .	A 182
24.9	24.7	23.3	22.4	21.8	21.4	21.2	21.0	20.8	20.6	20.3	20.0	19.1	14.9	11.6	9.0	6.9	5.2	. . .	
20.0	17.6	16.1	15.1	14.3	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.3	*9.9*	*7.1*	*5.0*	*3.6*	*2.5*	F310	A 182
20.0	20.0	20.0	19.9	19.3	18.5	18.2	17.9	17.7	17.4	17.2	16.9	*15.9*	*9.9*	*7.1*	*5.0*	*3.6*	*2.5*	F310	
20.0	17.6	16.1	15.1	14.3	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.3	*9.9*	*7.1*	*5.0*	*3.6*	*2.5*	F310	
20.0	20.0	20.0	19.9	19.3	18.5	18.2	17.9	17.7	17.4	17.2	16.9	*15.9*	*9.9*	*7.1*	*5.0*	*3.6*	*2.5*	F310	
20.0	17.3	15.6	14.3	13.3	12.6	12.3	12.1	11.9	11.8	11.6	11.5	11.4	11.3	11.2	11.1	*9.8*	*7.4*	F316	A 182
20.0	20.0	19.4	19.2	18.0	17.0	16.6	16.3	16.1	15.9	15.7	15.6	15.4	15.3	15.1	*12.4*	*9.8*	*7.4*	F316	
20.0	17.3	15.6	14.3	13.3	12.6	12.3	12.1	11.9	11.8	11.6	11.5	11.4	11.3	11.2	11.1	*9.8*	*7.4*	F316	
20.0	20.0	20.0	19.3	18.0	17.0	16.6	16.3	16.1	15.9	15.7	15.6	15.4	15.3	15.1	*12.4*	*9.8*	*7.4*	F316	
20.0	17.3	15.6	14.3	13.3	12.6	12.3	12.1	11.9	11.8	11.6	11.5	11.4	11.3	11.2	11.1	*9.8*	*7.4*	F316H	A 182
20.0	20.0	19.4	19.2	18.0	17.0	16.6	16.3	16.1	15.9	15.7	15.6	15.4	15.3	15.1	*12.4*	*9.8*	*7.4*	F316H	
20.0	17.3	15.6	14.3	13.3	12.6	12.3	12.1	11.9	11.8	11.6	11.5	11.4	11.3	11.2	11.1	*9.8*	*7.4*	F316H	
20.0	20.0	20.0	19.3	18.0	17.0	16.6	16.3	16.1	15.9	15.7	15.6	15.4	15.3	15.1	*12.4*	*9.8*	*7.4*	F316H	
16.7	14.1	12.7	11.7	10.9	10.4	10.2	10.0	9.8	9.6	9.4	9.2	8.9	8.8	8.0	*7.9*	6.5	6.4	F316L	A 182
16.7	16.7	16.7	15.6	14.8	14.0	13.8	13.5	13.2	13.0	12.7	12.4	12.0	11.9	10.8	10.2	8.8	6.4	F316L	
22.9	20.7	19.0	17.6	16.5	15.6	15.2	14.9	14.5	14.2	13.9	13.7	13.4	13.2	12.9	*12.3*	*9.8*	*7.4*	F316N	
22.9	22.9	22.0	21.5	21.2	21.0	20.5	20.0	19.6	19.2	18.8	18.5	18.1	17.8	*15.8*	*12.3*	*9.8*	*7.4*	F316N	
20.0	18.0	16.5	15.3	14.3	13.5	13.2	13.0	12.7	12.6	12.4	12.3	12.1	12.0	*9.6*	*6.9*	*5.0*	*3.6*	F321	A 182
20.0	19.0	17.8	17.5	17.5	17.5	17.5	17.5	17.2	16.9	16.7	16.5	16.4	*16.2*	*9.6*	*6.9*	*5.0*	*3.6*	F321	
20.0	18.0	16.5	15.3	14.3	13.5	13.2	13.0	12.7	12.6	12.4	12.3	12.1	12.0	*9.6*	*6.9*	*5.0*	*3.6*	F321	
20.0	20.0	19.1	18.7	18.7	18.3	17.9	17.5	17.2	16.9	16.7	16.5	16.4	*16.2*	*9.6*	*6.9*	*5.0*	*3.6*	F321	
20.0	18.0	16.5	15.3	14.3	13.5	13.2	13.0	12.7	12.6	12.4	12.3	12.1	12.0	11.9	*9.1*	*6.9*	*5.4*	F321H	A 182
20.0	19.0	17.8	17.5	17.5	17.5	17.5	17.5	17.2	16.9	16.7	16.5	16.4	16.2	*12.3*	*9.1*	*6.9*	*5.4*	F321H	
20.0	18.0	16.5	15.3	14.3	13.5	13.2	13.0	12.7	12.6	12.4	12.3	12.1	12.0	11.9	*9.1*	*6.9*	*5.4*	F321H	
20.0	20.0	19.1	18.7	18.7	18.3	17.9	17.5	17.2	16.9	16.7	16.5	16.4	16.2	*12.3*	*9.1*	*6.9*	*5.4*	F321H	
20.0	18.4	17.1	16.0	15.0	14.3	14.0	13.8	13.7	13.6	13.5	13.4	13.4	13.4	*12.1*	*9.1*	*6.1*	*4.4*	F347	A 182
20.0	19.1	17.6	16.6	16.0	15.8	15.7	15.7	15.7	15.7	15.7	15.6	15.5	15.3	*12.1*	*9.1*	*6.1*	*4.4*	F347	
20.0	18.4	17.1	16.0	15.0	14.3	14.0	13.8	13.7	13.6	13.5	13.4	13.4	13.4	*12.1*	*9.1*	*6.1*	*4.4*	F347	
20.0	20.0	18.8	17.8	17.2	16.9	16.8	16.8	16.8	16.8	16.8	16.7	16.6	*16.0*	*12.1*	*9.1*	*6.1*	*4.4*	F347	
20.0	18.4	17.1	16.0	15.0	14.3	14.0	13.8	13.7	13.6	13.5	13.4	13.4	13.4	13.4	13.3	*10.5*	*7.9*	F347H	A 182
20.0	19.1	17.6	16.6	16.0	15.7	15.7	15.7	15.7	15.7	15.7	15.6	15.5	15.3	15.1	*14.1*	*10.5*	*7.9*	F347H	
20.0	18.4	17.1	16.0	15.0	14.3	14.0	13.8	13.7	13.6	13.5	13.4	13.4	13.4	13.4	13.3	*10.5*	*7.9*	F347H	
20.0	20.0	18.8	17.8	17.1	16.9	16.8	16.8	16.8	16.8	16.8	16.7	16.6	16.4	16.2	*14.1*	*10.5*	*7.9*	F347H	
20.0	18.4	17.1	16.0	15.0	14.3	14.0	13.8	13.7	13.6	13.5	13.4	13.4	13.4	*12.1*	*9.1*	*6.1*	*4.4*	F348	A 182
20.0	19.1	17.6	16.6	16.0	15.8	15.7	15.7	15.7	15.7	15.7	15.6	15.5	15.3	*12.1*	*9.1*	*6.1*	*4.4*	F348	
20.0	18.4	17.1	16.0	15.0	14.3	14.0	13.8	13.7	13.6	13.5	13.4	13.4	13.4	*12.1*	*9.1*	*6.1*	*4.4*	F348	
20.0	20.0	18.8	17.8	17.2	16.9	16.8	16.8	16.8	16.8	16.8	16.7	16.6	*16.0*	*12.1*	*9.1*	*6.1*	*4.4*	F348	

Table A-3 Stainless Steels (Cont'd)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
Forgings (Cont'd)									
Austenitic (Cont'd)									
A 182	F348H	...	S34809	18Cr–10Ni–Cb	8	(12)	70	30	1.00
	F348H	...	S34809	18Cr–10Ni–Cb	8	(9)(12)	70	30	1.00
	F348H	...	S34809	18Cr–10Ni–Cb	8	...	75	30	1.00
	F348H	...	S34809	18Cr–10Ni–Cb	8	(9)	75	30	1.00
Ferritic/Martensitic									
A 182	FXM-27Cb	...	S44627	27Cr–1Mo	10I	(2)	60	35	1.00
A 336	FXM-27Cb	...	S44627	27Cr–1Mo	10I	(2)	60	35	1.00
Ferritic/Austenitic									
A 182	F51	...	S31803	22Cr–5.5Ni–3Mo–N	10H	(1)(33)(34)	90	65	1.00
(A08)	F60	...	S32205	22Cr–5.5Ni–3Mo–N	10H	(1)(33)(34)	95	70	1.00
(A08)	F53	...	S32750	25Cr–7Ni–4Mo–N	10H	(1)(33)(39)	116	80	1.00
Fittings (Seamless and Welded)									
Austenitic									
A 403	WP304	...	S30400	18Cr–8Ni	8	(1)(4)(7)(10)(11)	75	30	1.00
	WP304	...	S30400	18Cr–8Ni	8	(1)(4)(7)(9)(10)(11)	75	30	1.00
	WP304H	...	S30409	18Cr–8Ni	8	(1)(4)(7)(11)	75	30	1.00
	WP304H	...	S30409	18Cr–8Ni	8	(1)(4)(7)(9)(11)	75	30	1.00
A 403	WP304L	...	S30403	18Cr–8Ni	8	(1)(7)(11)	70	25	1.00
	WP304L	...	S30403	18Cr–8Ni	8	(1)(7)(9)(11)	70	25	1.00
	WP304N	...	S30451	18Cr–8Ni–N	8	(1)(4)(7)(10)	80	35	1.00
	WP304N	...	S30451	18Cr–8Ni–N	8	(1)(4)(7)(9)(10)	80	35	1.00
A 403	WP309	...	S30900	23Cr–12Ni	8	(1)(7)(10)(11)	75	30	1.00
	WP309	...	S30900	23Cr–12Ni	8	(1)(7)(9)(10)(11)	75	30	1.00
	WP310	...	S31000	23Cr–20Ni	8	(1)(7)(10)(11)(14)	75	30	1.00
	WP310	...	S31000	23Cr–20Ni	8	(1)(7)(9)(10)(11)(14)	75	30	1.00
	WP310	...	S31000	23Cr–20Ni	8	(1)(7)(10)(11)(15)	75	30	1.00
	WP310	...	S31000	23Cr–20Ni	8	(1)(7)(9)(10)(11)(15)	75	30	1.00
A 403	WP316	...	S31600	16Cr–12Ni–2Mo	8	(4)(7)(10)(11)	75	30	1.00
	WP316	...	S31600	16Cr–12Ni–2Mo	8	(4)(7)(9)(10)(11)	75	30	1.00
	WP316H	...	S31609	16Cr–12Ni–2Mo	8	(4)(7)(11)	75	30	1.00
	WP316H	...	S31609	16Cr–12Ni–2Mo	8	(4)(7)(9)(11)	75	30	1.00
A 403	WP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)(7)(11)	70	25	1.00
	WP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)(7)(9)(11)	70	25	1.00
	WP316N	...	S31651	16Cr–12Ni–2Mo–N	8	(1)(7)(10)	80	35	1.00
	WP316N	...	S31651	16Cr–12Ni–2Mo–N	8	(1)(7)(9)(10)	80	35	1.00
A 403	WP317	...	S31700	18Cr–13Ni–3Mo	8	(1)(7)(10)(11)	75	30	1.00
	WP317	...	S31700	18Cr–13Ni–3Mo	8	(1)(7)(9)(10)(11)	75	30	1.00
	WP321	...	S32100	18Cr–10Ni–Ti	8	(4)(7)(10)(11)	75	30	1.00
	WP321	...	S32100	18Cr–10Ni–Ti	8	(4)(7)(9)(10)(11)	75	30	1.00
	WP321H	...	S32109	18Cr–10Ni–Ti	8	(4)(7)(11)	75	30	1.00
	WP321H	...	S32109	18Cr–10Ni–Ti	8	(4)(7)(9)(11)	75	30	1.00

Table A-3 Stainless Steels (Cont'd)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																				
−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1,000	1,050	1,100	1,150	1,200	Type or Grade	Spec. No.	
																		Forgings (Cont'd) Austenitic (Cont'd)		
20.0	18.4	17.1	16.0	15.0	14.3	14.0	13.8	13.7	13.6	13.5	13.4	13.4	13.4	13.4	13.3	*10.5*	*7.9*	F348H	A 182	
20.0	19.1	17.6	16.6	16.0	15.7	15.7	15.7	15.7	15.7	15.7	15.6	15.5	15.3	15.1	*14.1*	*10.5*	*7.9*	F348H		
20.0	18.4	17.1	16.0	15.0	14.3	14.0	13.8	13.7	13.6	13.5	13.4	13.4	13.4	13.4	13.3	*10.5*	*7.9*	F348H		
20.0	20.0	18.8	17.8	17.1	16.9	16.8	16.8	16.8	16.8	16.8	16.7	16.6	16.4	16.2	*14.1*	*10.5*	*7.9*	F348H		
																		Ferritic/Martensitic		
17.1	17.1	16.6	16.1	16.1	16.1	16.1	...	...	...	...	...	...	...	...	...	...	...	FXM-27Cb	A 182	
17.1	17.1	16.6	16.1	16.1	16.1	16.1	...	...	...	...	...	...	...	...	...	...	...	FXM-27Cb	A 336	
																		Ferritic/Austenitic		
25.7	25.7	24.8	23.9	23.3	23.1	...	...	...	...	...	...	...	...	...	...	...	...	F51	A 182	
27.1	27.1	26.2	25.2	24.6	24.3	...	...	...	...	...	...	...	...	...	...	...	...	F60		**(A08)**
33.1	33.0	31.2	30.1	29.6	29.4	...	...	...	...	...	...	...	...	...	...	...	...	F53		**(A08)**
																		Fittings (Seamless and Welded) Austenitic		
20.0	16.7	15.0	13.8	12.9	12.3	12.0	11.7	11.5	11.2	11.0	10.8	10.6	10.4	10.1	*9.8*	*7.7*	*6.1*	WP304	A 403	
20.0	20.0	18.9	18.3	17.5	16.6	16.2	15.8	15.5	15.2	14.9	14.6	14.3	14.0	*12.4*	*9.8*	*7.7*	*6.1*	WP304		
20.0	16.7	15.0	13.8	12.9	12.3	12.0	11.7	11.5	11.2	11.0	10.8	10.6	10.4	10.1	*9.8*	*7.7*	*6.1*	WP304H		
20.0	20.0	18.9	18.3	17.5	16.6	16.2	15.8	15.5	15.2	14.9	14.6	14.3	14.0	*12.4*	*9.8*	*7.7*	*6.1*	WP304H		
16.7	14.3	12.8	11.7	10.9	10.4	10.2	10.0	9.8	9.7	...	...	...	...	...	...	...	...	WP304L	A 403	
16.7	16.7	16.7	15.8	14.7	14.0	13.7	13.5	13.3	13.0	...	...	...	...	...	...	...	...	WP304L		
22.9	19.1	16.7	15.1	14.0	13.3	13.0	12.8	12.5	12.3	12.1	11.8	11.6	11.3	11.0	*9.8*	*7.7*	*6.1*	WP304N		
22.9	22.9	21.7	20.3	18.9	17.9	17.5	17.2	16.9	16.6	16.3	16.0	15.6	15.2	*12.4*	*9.8*	*7.7*	*6.1*	WP304N		
20.0	17.5	16.1	15.1	14.4	13.9	13.7	13.5	13.3	13.1	12.9	12.7	12.5	*9.9*	*7.1*	*5.0*	*3.6*	*2.5*	WP309	A 403	
20.0	20.0	20.0	20.0	19.4	18.8	18.5	18.2	18.0	17.7	17.5	17.2	*15.9*	*9.9*	*7.1*	*5.0*	*3.6*	*2.5*	WP309		
20.0	17.6	16.1	15.1	14.3	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.3	*9.9*	*7.1*	*5.0*	*3.6*	*2.5*	WP310		
20.0	20.0	20.0	19.9	19.3	18.5	18.2	17.9	17.7	17.4	17.2	16.9	*15.9*	*9.9*	*7.1*	*5.0*	*3.6*	*2.5*	WP310		
20.0	17.6	16.1	15.1	14.3	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.3	*9.9*	*7.1*	*5.0*	*3.6*	*2.5*	WP310		
20.0	20.0	20.0	19.9	19.3	18.5	18.2	17.9	17.7	17.4	17.2	16.9	*15.9*	*9.9*	*7.1*	*5.0*	*3.6*	*2.5*	WP310		
20.0	17.3	15.6	14.3	13.3	12.6	12.3	12.1	11.9	11.8	11.6	11.5	11.4	11.3	11.2	11.1	*9.8*	*7.4*	WP316	A 403	
20.0	20.0	20.0	19.3	18.0	17.0	16.6	16.3	16.1	15.9	15.7	15.6	15.4	15.3	15.1	*12.4*	*9.8*	*7.4*	WP316		
20.0	17.3	15.6	14.3	13.3	12.6	12.3	12.1	11.9	11.8	11.6	11.5	11.4	11.3	11.2	11.1	*9.8*	*7.4*	WP316H		
20.0	20.0	20.0	19.3	18.0	17.0	16.6	16.3	16.1	15.9	15.7	15.6	15.4	15.3	15.1	*12.4*	*9.8*	*7.4*	WP316H		
16.7	14.1	12.7	11.7	10.9	10.4	10.2	10.0	9.8	9.6	9.4	9.2	8.9	8.8	8.0	7.9	6.5	6.4	WP316L	A 403	
16.7	16.7	16.0	15.6	14.8	14.0	13.8	13.5	13.2	13.0	12.7	12.4	12.0	11.9	10.8	10.2	8.8	6.4	WP316L		
22.9	20.7	19.0	17.6	16.5	15.6	15.2	14.9	14.5	14.2	13.9	13.7	13.4	13.2	12.9	*12.3*	*9.8*	*7.4*	WP316N		
22.9	22.9	22.0	21.5	21.2	21.0	20.5	20.0	19.6	19.2	18.8	18.5	18.1	17.8	*15.8*	*12.3*	*9.8*	*7.4*	WP316N		
20.0	17.3	15.6	14.3	13.3	12.6	12.3	12.1	11.9	11.8	11.6	11.5	11.4	11.3	11.2	11.1	*9.8*	*7.4*	WP317	A 403	
20.0	20.0	20.0	19.3	18.0	17.0	16.6	16.3	16.1	15.9	15.7	15.6	15.4	15.3	15.1	*12.4*	*9.8*	*7.4*	WP317		
20.0	18.0	16.5	15.3	14.3	13.5	13.2	13.0	12.7	12.6	12.4	12.3	12.1	12.0	*9.6*	*6.9*	*5.0*	*3.6*	WP321		
20.0	20.0	19.1	18.7	18.7	18.3	17.9	17.5	17.2	16.9	16.7	16.5	16.4	*16.2*	*9.6*	*6.9*	*5.0*	*3.6*	WP321		
20.0	18.0	16.5	15.3	14.3	13.5	13.2	13.0	12.7	12.6	12.4	12.3	12.1	12.0	11.9	*9.1*	*6.9*	*5.4*	WP321H		
20.0	20.0	19.1	18.7	18.7	18.3	17.9	17.5	17.2	16.9	16.7	16.5	16.4	16.2	*12.3*	*9.1*	*6.9*	*5.4*	WP321H		

Table A-3 Stainless Steels (Cont'd)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
Fittings (Seamless and Welded) (Cont'd)									
Austenitic (Cont'd)									
A 403	WP347	...	S34700	18Cr–10Ni–Cb	8	(4)(7)(10)(11)	75	30	1.00
	WP347	...	S34700	18Cr–10Ni–Cb	8	(4)(7)(9)(10)(11)	75	30	1.00
	WP347H	...	S34709	18Cr–10Ni–Cb	8	(4)(7)(11)	75	30	1.00
	WP347H	...	S34709	18Cr–10Ni–Cb	8	(4)(7)(9)(11)	75	30	1.00
A 403	WP348	...	S34800	18Cr–10Ni–Cb	8	(4)(7)(10)(11)	75	30	1.00
	WP348	...	S34800	18Cr–10Ni–Cb	8	(4)(7)(9)(10)(11)	75	30	1.00
	WP348H	...	S34809	18Cr–10Ni–Cb	8	(4)(7)(11)	75	30	1.00
	WP348H	...	S34809	18Cr–10Ni–Cb	8	(4)(7)(9)(11)	75	30	1.00
Ferritic/Austenitic									
A 815	S31803	...	S31803	22Cr–5.5Ni–3Mo–N	10H	(1)(33)(34)	90	65	1.00
(A08)	S32205	...	S32205	22Cr–5.5Ni–3Mo–N	10H	(1)(33)(34)	95	70	1.00
Castings									
Austenitic									
A 351	CF3	...	J92500	18Cr–8Ni	8	(1)(5)(26)	70	30	0.80
	CF3	...	J92500	18Cr–8Ni	8	(1)(5)(9)(26)	70	30	0.80
	CF3A	...	J92500	18Cr–8Ni	8	(1)(5)(26)	77.5	35	0.80
	CF3A	...	J92500	18Cr–8Ni	8	(1)(5)(9)(26)	77.5	35	0.80
	CF3M	...	J92800	18Cr–12Ni–2Mo	8	(1)(5)(13)(26)	70	30	0.80
	CF3M	...	J92800	18Cr–12Ni–2Mo	8	(1)(5)(9)(13)(26)	70	30	0.80
A 351	CF8	...	J92600	18Cr–8Ni	8	(5)(10)(26)	70	30	0.80
	CF8	...	J92600	18Cr–8Ni	8	(5)(9)(10)(26)	70	30	0.80
	CF8C	...	J92710	18Cr–10Ni–Cb	8	(1)(5)(10)(26)	70	30	0.80
	CF8C	...	J92710	18Cr–10Ni–Cb	8	(1)(5)(9)(10)(26)	70	30	0.80
	CF8M	...	J92900	16Cr–12Ni–2Mo	8	(5)(13)(26)	70	30	0.80
	CF8M	...	J92900	16Cr–12Ni–2Mo	8	(5)(9)(13)(26)	70	30	0.80
A 351	CH8	...	J93400	25Cr–12Ni	8	(1)(5)(10)(26)	65	28	0.80
	CH8	...	J93400	25Cr–12Ni	8	(1)(5)(9)(10)(26)	65	28	0.80
	CH20	...	J93402	25Cr–12Ni	8	(1)(5)(10)(26)	70	30	0.80
	CH20	...	J93402	25Cr–12Ni	8	(1)(5)(9)(10)(26)	70	30	0.80
	CK20	...	J94202	25Cr–20Ni	8	(1)(5)(10)(26)	65	28	0.80
	CK20	...	J94202	25Cr–20Ni	8	(1)(5)(9)(10)(26)	65	28	0.80
Ferritic/Martensitic									
A 217	CA15	...	J91150	13Cr–½Mo	6	(1)(3)(5)	90	65	0.80
Bolts, Nuts, and Studs									
Austenitic									
A 193	B8	1	S30400	18Cr–8Ni	...	(10)(11)(16)	75	30	...
	B8C	1	S34700	18Cr–10Ni–Cb	...	(10)(11)(16)	75	30	...
	B8M	1	S31600	16Cr–12Ni–2Mo	...	(10)(11)(16)	75	30	...
	B8T	1	S32100	18Cr–10Ni–Ti	...	(10)(11)(16)	75	30	...
A 193	B8	2	S30400	18Cr–8Ni	...	(16)(18)(20)	125	100	...
	B8	2	S30400	18Cr–8Ni	...	(16)(18)(21)	115	80	...
	B8	2	S30400	18Cr–8Ni	...	(16)(18)(22)	105	65	...
	B8	2	S30400	18Cr–8Ni	...	(16)(18)(23)	100	50	...

Table A-3 Stainless Steels (Cont'd)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																				
−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1,000	1,050	1,100	1,150	1,200	Type or Grade	Spec. No.	
Fittings (Seamless and Welded) (Cont'd) Austenitic (Cont'd)																				
20.0	18.4	17.1	16.0	15.0	14.3	14.0	13.8	13.7	13.6	13.5	13.4	13.4	13.4	*12.1*	*9.1*	*6.1*	*4.4*	WP347	A 403	
20.0	20.0	18.8	17.8	17.2	16.9	16.8	16.8	16.8	16.8	16.8	16.7	16.6	*16.0*	*12.1*	*9.1*	*6.1*	*4.4*	WP347		
20.0	18.4	17.1	16.0	15.0	14.3	14.0	13.8	13.7	13.6	13.5	13.4	13.4	13.4	13.4	13.3	*10.5*	*7.9*	WP347H		
20.0	20.0	18.8	17.8	17.1	16.9	16.8	16.8	16.8	16.8	16.8	16.7	16.6	16.4	16.2	*14.1*	*10.5*	*7.9*	WP347H		
20.0	18.4	17.1	16.0	15.0	14.3	14.0	13.8	13.7	13.6	13.5	13.4	13.4	13.4	*12.1*	*9.1*	*6.1*	*4.4*	WP348	A 403	
20.0	20.0	18.8	17.8	17.2	16.9	16.8	16.8	16.8	16.8	16.8	16.7	16.6	*16.0*	*12.1*	*9.1*	*6.1*	*4.4*	WP348		
20.0	18.4	17.1	16.0	15.0	14.3	14.0	13.8	13.7	13.6	13.5	13.4	13.4	13.4	13.4	13.3	*10.5*	*7.9*	WP348H		
20.0	20.0	18.8	17.8	17.1	16.9	16.8	16.8	16.8	16.8	16.8	16.7	16.6	16.4	16.2	*14.1*	*10.5*	*7.9*	WP348H		
Ferritic/Austenitic																				
25.7	25.7	24.8	23.9	23.3	23.1	...	...	...	...	...	...	...	...	...	...	...	...	S31803	A 815	
27.1	27.1	26.2	25.2	24.6	24.3	...	...	...	...	...	...	...	...	...	...	...	...	S32205		**(A08)**
Castings Austenitic																				
16.0	13.3	12.0	11.0	10.4	9.8	9.6	9.4	9.2	9.0	...	...	...	...	...	...	...	...	CF3	A 351	
16.0	15.2	14.1	13.7	13.5	13.3	13.0	12.7	12.4	12.1	...	...	...	...	...	...	...	...	CF3		
17.7	15.6	14.0	12.9	12.1	11.5	11.2	10.9	...	...	...	...	...	...	...	...	...	...	CF3A		
17.7	16.8	15.6	15.1	15.0	15.0	15.0	14.8	...	...	...	...	...	...	...	...	...	...	CF3A		
16.0	13.8	12.4	11.4	10.6	10.1	9.8	9.7	9.5	9.4	9.3	...	...	...	...	...	...	...	CF3M		
16.0	16.0	15.5	15.4	14.3	13.6	13.3	13.0	12.8	12.7	12.5	...	...	...	...	...	...	...	CF3M		
16.0	13.3	12.0	11.0	10.4	9.8	9.6	9.4	9.2	9.0	8.8	8.6	8.5	8.3	*7.6*	*6.0*	*4.8*	*3.8*	CF8	A 351	
16.0	15.2	14.1	13.7	13.5	13.3	13.0	12.7	12.4	12.1	11.9	11.7	11.4	*9.8*	*7.6*	*6.0*	*4.8*	*3.8*	CF8		
16.0	13.3	12.0	11.0	10.4	9.8	9.6	9.4	9.2	9.0	8.8	8.6	8.5	8.3	8.1	*7.3*	*4.9*	*3.6*	CF8C		
16.0	15.2	14.1	13.7	13.5	13.3	13.0	12.7	12.4	12.1	11.9	11.7	11.4	11.2	*9.7*	*7.3*	*4.9*	*3.6*	CF8C		
16.0	13.8	12.4	11.4	10.6	10.1	9.8	9.7	9.5	9.4	9.3	9.2	9.1	9.1	9.0	*7.1*	*5.5*	*4.3*	CF8M		
16.0	16.0	15.5	15.4	14.3	13.6	13.3	13.0	12.8	12.7	12.5	12.4	12.3	*11.9*	*9.2*	*7.1*	*5.5*	*4.3*	CF8M		
14.9	12.2	11.3	10.8	10.5	10.1	9.9	9.7	9.4	9.1	8.8	8.5	8.2	7.9	*6.8*	*5.2*	*4.0*	*3.0*	CH8	A 351	
14.9	13.6	12.7	12.3	12.3	12.3	12.3	12.2	12.0	11.8	11.5	11.1	10.6	*8.9*	*6.8*	*5.2*	*4.0*	*3.0*	CH8		
16.0	13.1	12.1	11.6	11.2	10.8	10.6	10.4	10.1	9.8	9.5	9.1	8.8	8.5	*6.8*	*5.2*	*4.0*	*3.0*	CH20		
16.0	14.6	13.6	13.3	13.2	13.2	13.2	13.1	13.0	12.7	12.4	11.9	11.4	*8.9*	*6.8*	*5.2*	*4.0*	*3.0*	CH20		
14.9	12.2	11.3	10.8	10.5	10.1	9.9	9.7	9.4	9.1	8.8	8.5	8.2	7.9	7.6	*6.8*	*5.8*	*4.8*	CK20		
14.9	13.6	12.7	12.3	12.3	12.3	12.3	12.2	12.0	11.8	11.5	11.1	10.6	*9.0*	*7.8*	*6.8*	*5.8*	*4.8*	CK20		
Ferritic/Martensitic																				
20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.1	*12.0*	*7.4*	*4.7*	*3.0*	*1.9*	*1.2*	*0.8*	CA15	A 217	
Bolts, Nuts, and Studs Austenitic																				
18.8	16.7	15.0	13.8	12.9	12.1	12.0	11.8	11.5	11.2	11.0	10.8	10.6	10.4	10.1	*9.8*	*7.7*	*6.1*	B8	A 193	
18.8	17.9	16.4	15.5	15.0	14.3	14.1	13.8	13.7	13.6	13.5	13.5	13.4	13.4	*12.1*	*9.1*	*6.1*	*4.4*	B8C		
18.8	17.7	15.6	14.3	13.3	12.6	12.3	12.1	11.9	11.7	11.6	11.5	11.4	11.3	11.2	11.0	*9.8*	*7.4*	B8M		
18.8	17.8	16.5	15.3	14.3	13.5	13.3	12.9	12.7	12.5	12.4	12.3	12.1	12.0	*9.6*	*6.9*	*5.0*	*3.6*	B8T		
25.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8	A 193	
20.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8		
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8		
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8		

Table A-3 Stainless Steels (Cont'd)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
Bolts, Nuts, and Studs (Cont'd)									
Austenitic (Cont'd)									
A 193	B8C	2	S34700	18Cr–10Ni–Cb	...	(16)(18)(20)	125	100	...
	B8C	2	S34700	18Cr–10Ni–Cb	...	(16)(18)(21)	115	80	...
	B8C	2	S34700	18Cr–10Ni–Cb	...	(16)(18)(22)	105	65	...
	B8C	2	S34700	18Cr–10Ni–Cb	...	(16)(18)(23)	100	50	...
A 193	B8M	2	S31600	16Cr–12Ni–2Mo	...	(16)(18)(20)	110	80	...
	B8M	2	S31600	16Cr–12Ni–2Mo	...	(16)(18)(21)	100	80	...
	B8M	2	S31600	16Cr–12Ni–2Mo	...	(16)(18)(22)	95	75	...
	B8M	2	S31600	16Cr–12Ni–2Mo	...	(16)(18)(23)	90	65	...
A 193	B8T	2	S32100	18Cr–10Ni–Ti	...	(16)(18)(20)	125	100	...
	B8T	2	S32100	18Cr–10Ni–Ti	...	(16)(18)(21)	115	80	...
	B8T	2	S32100	18Cr–10Ni–Ti	...	(16)(18)(22)	105	65	...
	B8T	2	S32100	18Cr–10Ni–Ti	...	(16)(18)(23)	100	50	...
A 194	8	...	S30400	18Cr–8Ni	...	(17)	...	...	...
	8C	...	S34700	18Cr–10Ni–Cb	...	(17)	...	...	...
A 194	8M	...	S31600	16Cr–12Ni–Mo	...	(17)	...	...	...
	8T	...	S32100	18Cr–10Ni–Ti	...	(17)	...	...	...
	8F	...	...	18Cr–8Ni–Fm	...	(17)	...	...	...
A 320	B8	1	S30400	18Cr–8Ni	...	(16)(18)	75	30	...
	B8	1	S30400	18Cr–8Ni	...	(16)(28)	75	30	...
	B8	2	S30400	18Cr–8Ni	...	(16)(18)(23)	100	50	...
	B8	2	S30400	18Cr–8Ni	...	(16)(18)(22)	105	65	...
	B8	2	S30400	18Cr–8Ni	...	(16)(18)(21)	115	80	...
	B8	2	S30400	18Cr–8Ni	...	(16)(18)(20)	125	100	...
A 320	B8C	1	S34700	18Cr–10Ni–Cb	...	(16)	75	30	...
	B8C	1	S34700	18Cr–10Ni–Cb	...	(16)(28)	75	30	...
	B8C	2	S34700	18Cr–10Ni–Cb	...	(16)(18)(23)	100	50	...
	B8C	2	S34700	18Cr–10Ni–Cb	...	(16)(18)(22)	105	65	...
	B8C	2	S34700	18Cr–10Ni–Cb	...	(16)(18)(21)	115	80	...
	B8C	2	S34700	18Cr–10Ni–Cb	...	(16)(18)(20)	125	100	...
A 320	B8M	1	S31600	16Cr–12Ni–2Mo	...	(16)	75	30	...
	B8M	1	S31600	16Cr–12Ni–2Mo	...	(16)(28)	75	30	...
	B8M	2	S31600	16Cr–12Ni–2Mo	...	(16)(18)(23)	90	50	...
	B8M	2	S31600	16Cr–12Ni–2Mo	...	(16)(18)(22)	95	65	...
	B8M	2	S31600	16Cr–12Ni–2Mo	...	(16)(18)(21)	100	80	...
	B8M	2	S31600	16Cr–12Ni–2Mo	...	(16)(18)(20)	110	95	...
A 320	B8T	1	S32100	18Cr–10Ni–Ti	...	(16)	75	30	...
	B8T	1	S32100	18Cr–10Ni–Ti	...	(16)(28)	75	30	...
	B8T	2	S32100	18Cr–10Ni–Ti	...	(16)(18)(23)	100	50	...
	B8T	2	S32100	18Cr–10Ni–Ti	...	(16)(18)(22)	105	65	...
	B8T	2	S32100	18Cr–10Ni–Ti	...	(16)(18)(21)	115	80	...
	B8T	2	S32100	18Cr–10Ni–Ti	...	(16)(18)(20)	125	100	...

Table A-3 Stainless Steels (Cont'd)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																			
−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1,000	1,050	1,100	1,150	1,200	Type or Grade	Spec. No.
																		Bolts, Nuts, and Studs (Cont'd)	
																		Austenitic (Cont'd)	
25.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	A 193
20.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	
22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	...	...	...	...	...	...	...	...	...	B8M	A 193
20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	...	...	...	...	...	...	...	...	...	B8M	
18.8	17.7	16.3	16.3	16.3	16.3	16.3	16.3	16.3	...	...	...	...	...	...	...	...	...	B8M	
18.8	17.7	15.6	14.3	13.3	12.6	12.5	12.5	12.5	...	...	...	...	...	...	...	...	...	B8M	
25.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	A 193
20.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8	A 194
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8C	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8M	A 194
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8T	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8F	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8	A 320
18.8	16.7	15.0	13.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8	
20.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8	
25.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	A 320
18.8	18.4	17.1	16.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	
20.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	
25.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8M	A 320
18.8	17.7	15.6	14.3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8M	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8M	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8M	
20.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8M	
22.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8M	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	A 320
18.8	17.8	16.5	15.3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	
20.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	
25.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	

(07)

Table A-3 Stainless Steels (Cont'd)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Bolts, Nuts, and Studs (Cont'd)									
Austenitic (Cont'd)									
(A08) A 453	660	A & B	S66286	15Cr–25Ni–Mo–Ti–V–B	...	(16)	130	85	...
A 479	309H	...	S30909	23Cr–12Ni	8	(9)	75	30	...
	309H	...	S30909	23Cr–12Ni	8	...	75	30	...
	310H	...	S31009	25Cr–20Ni	8	(9)	75	30	...
	310H	...	S31009	25Cr–20Ni	8	...	75	30	...
A 564	630	H1100	S17400	17Cr–4Ni–3.5Cu–0.04P	...	(16)(24)	140	115	...
Ferritic/Martensitic									
A 193	B6	(410)	S41000	13Cr	...	(16)(19)	110	85	...
A 194	6	...	S41000	13Cr	...	(17)	...	...	...
Bar									
Austenitic									
A 479	304	...	S30400	18Cr–8Ni	8	(10)	75	30	1.00
	304	...	S30400	18Cr–8Ni	8	(9)(10)	75	30	1.00
	304H	...	S30409	18Cr–8Ni	8	...	75	30	1.00
	304H	...	S30409	18Cr–8Ni	8	(9)	75	30	1.00
A 479	304L	...	S30403	18Cr–8Ni	8	(25)	70	25	1.00
	304L	...	S30403	18Cr–8Ni	8	(9)(25)	70	25	1.00
	304N	...	S30451	18Cr–8Ni–N	8	(10)	80	35	1.00
	304N	...	S30451	18Cr–8Ni–N	8	(9)(10)	80	35	1.00
A 479	...	...	S30815	21Cr–11Ni–N	8	(1)	87	45	1.00
	...	...	S30815	21Cr–11Ni–N	8	(1)(9)	87	45	1.00
A 479	310S	...	S31008	25Cr–20Ni	8	(10)(11)(15)	75	30	1.00
	310S	...	S31008	25Cr–20Ni	8	(10)(11)(14)	75	30	1.00
	310S	...	S31008	25Cr–20Ni	8	(9)(10)(11)	75	30	1.00
A 479	316	...	S31600	16Cr–12Ni–2Mo	8	(10)	75	30	1.00
	316	...	S31600	16Cr–12Ni–2Mo	8	(9)(10)	75	30	1.00
	316H	...	S31609	16Cr–12Ni–2Mo	8	...	75	30	1.00
	316H	...	S31609	16Cr–12Ni–2Mo	8	(9)	75	30	1.00
A 479	316L	...	S31603	16Cr–12Ni–2Mo	8	(1)(25)(38)	70	25	1.00
	316L	...	S31603	16Cr–12Ni–2Mo	8	(1)(9)(25)(38)	70	25	1.00
	316N	...	S31651	16Cr–12Ni–2Mo	8	(10)	80	35	1.00
	316N	...	S31651	16Cr–12Ni–2Mo	8	(9)(10)	80	35	1.00
A 479	321	...	S32100	18Cr–10Ni–Ti	8	(10)	75	30	1.00
	321	...	S32100	18Cr–10Ni–Ti	8	(9)(10)	75	30	1.00
	321H	...	S32109	18Cr–10Ni–Ti	8	...	75	30	1.00
	321H	...	S32109	18Cr–10Ni–Ti	8	(9)	75	30	1.00
	...	...	S32550	25.5Cr–5.5Ni–3.5Mo–2Cu	10H	(1)(35)(36)	110	80	1.00

Table A-3 Stainless Steels (Cont'd)

(07)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																			
−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1,000	1,050	1,100	1,150	1,200	Type or Grade	Spec. No.
																			Bolts, Nuts, and Studs (Cont'd) Austenitic (Cont'd)
21.3	21.3	21.3	21.3	21.3	21.3	21.3	21.3	21.3	21.3	21.3	21.3	21.3	21.3	...	...	...	...	660	A 453 **(A08)**
20.0	20.0	20.0	20.0	19.4	18.8	18.5	18.2	18.0	17.7	17.5	17.2	16.9	*13.8*	*10.3*	*7.6*	*5.5*	*4.0*	309H	A 479
20.0	17.5	16.1	15.1	14.4	13.9	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.3	*10.3*	*7.6*	*5.5*	*4.0*	309H	
20.0	17.6	16.1	15.1	14.3	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.3	12.1	*10.3*	*7.6*	*5.5*	*4.0*	310H	
20.0	20.0	20.0	19.9	19.3	18.5	18.2	17.9	17.7	17.4	17.2	16.9	16.7	*13.8*	*10.3*	*7.6*	*5.5*	*4.0*	310H	
28.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	630	A 564
																			Ferritic/Martensitic
21.3	19.5	18.9	18.5	18.3	17.9	17.6	17.2	16.7	16.1	15.3	*12.3*	...	...	...	...	...	...	B6	A 193
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6	A 194
																			Bar Austenitic
20.0	16.7	15.0	13.8	12.9	12.3	12.0	11.7	11.5	11.2	11.0	10.8	10.6	10.4	10.1	*9.8*	*7.7*	*6.1*	304	A 479
20.0	20.0	18.9	18.3	17.5	16.6	16.2	15.8	15.5	15.2	14.9	14.6	14.3	14.0	*12.4*	*9.8*	*7.7*	*6.1*	304	
20.0	16.7	15.0	13.8	12.9	12.3	12.0	11.7	11.5	11.2	11.0	10.8	10.6	10.4	10.1	*9.8*	*7.7*	*6.1*	304H	
20.0	20.0	18.9	18.3	17.5	16.6	16.2	15.8	15.5	15.2	14.9	14.6	14.3	14.0	*12.4*	*9.8*	*7.7*	*6.1*	304H	
16.7	14.3	12.8	11.7	10.9	10.4	10.2	10.0	9.8	9.7	...	...	...	...	...	...	...	...	304L	A 479
16.7	16.7	16.7	15.8	14.7	14.0	13.7	13.5	13.3	13.0	...	...	...	...	...	...	...	...	304L	
22.9	19.1	16.7	15.1	14.0	13.3	13.0	12.8	12.5	12.3	12.1	11.8	11.6	11.3	11.0	*9.8*	*7.7*	*6.1*	304N	
22.9	22.9	21.7	20.3	18.9	17.9	17.5	17.2	16.9	16.6	16.3	16.0	15.6	15.2	*12.4*	*9.8*	*7.7*	*6.1*	304N	
24.9	24.7	22.0	19.9	18.5	17.7	17.4	17.2	17.0	16.8	16.6	16.4	16.2	14.9	11.6	9.0	6.9	5.2	...	A 479
24.9	24.7	23.3	22.4	21.8	21.4	21.2	21.0	20.8	20.6	20.3	20.0	19.1	14.9	11.6	9.0	6.9	5.2	...	
20.0	17.6	16.1	15.1	14.3	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.3	*9.9*	...	...	...	...	310S	A 479
20.0	17.6	16.1	15.1	14.3	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.3	*9.9*	...	...	...	...	310S	
20.0	20.0	20.0	19.9	19.3	18.5	18.2	17.9	17.7	17.4	17.2	16.9	*15.9*	*9.9*	...	...	...	...	310S	
20.0	17.3	15.6	14.3	13.3	12.6	12.3	12.1	11.9	11.8	11.6	11.5	11.4	11.3	11.2	11.1	*9.8*	*7.4*	316	A 479
20.0	20.0	20.0	19.3	18.0	17.0	16.6	16.3	16.1	15.9	15.7	15.6	15.4	15.3	15.1	*12.4*	*9.8*	*7.4*	316	
20.0	17.3	15.6	14.3	13.3	12.6	12.3	12.1	11.9	11.8	11.6	11.5	11.4	11.3	11.2	11.1	*9.8*	*7.4*	316H	
20.0	20.0	20.0	19.3	18.0	17.0	16.6	16.3	16.1	15.9	15.7	15.6	15.4	15.3	15.1	*12.4*	*9.8*	*7.4*	316H	
16.7	14.1	12.7	11.7	10.9	10.4	10.2	10.0	9.8	9.6	9.4	9.2	8.9	8.8	8.0	7.9	6.5	6.4	316L	A 479
16.7	16.7	16.0	15.6	14.8	14.0	13.8	13.5	13.2	13.0	12.7	12.4	12.0	11.9	10.8	10.2	8.8	6.4	316L	
22.9	20.7	19.0	17.6	16.5	15.6	15.2	14.9	14.5	14.2	13.9	13.7	13.4	13.2	12.9	*12.3*	*9.8*	*7.4*	316N	
22.9	22.9	22.0	21.5	21.2	21.0	20.5	20.0	19.6	19.2	18.8	18.5	18.1	17.8	*15.8*	*12.3*	*9.8*	*7.4*	316N	
20.0	18.0	16.5	15.3	14.3	13.5	13.2	13.0	12.7	12.6	12.4	12.3	12.1	12.0	*9.6*	*6.9*	*5.0*	*3.6*	321	A 479
20.0	20.0	19.1	18.7	18.7	18.3	17.9	17.5	17.2	16.9	16.7	16.5	16.4	*14.9*	*9.6*	*6.9*	*5.0*	*3.6*	321	
20.0	18.0	16.5	15.3	14.3	13.5	13.2	13.0	12.7	12.6	12.4	12.3	12.1	12.0	11.9	*9.1*	*6.9*	*5.4*	321H	
20.0	20.0	19.1	18.7	18.7	18.3	17.9	17.5	17.2	16.9	16.7	16.5	16.4	16.2	*12.3*	*9.1*	*6.9*	*5.4*	321H	
31.4	31.3	29.5	28.6	28.2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	

(07)

Table A-3 Stainless Steels (Cont'd)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Bar (Cont'd)									
Austenitic (Cont'd)									
A 479	347	...	S34700	18Cr–10Ni–Cb	8	(10)	75	30	1.00
	347	...	S34700	18Cr–10Ni–Cb	8	(9)(10)	75	30	1.00
	347H	...	S34709	18Cr–10Ni–Cb	8	...	75	30	1.00
	347H	...	S34709	18Cr–10Ni–Cb	8	(9)	75	30	1.00
A 479	348	...	S34800	18Cr–10Ni–Cb	8	(10)	75	30	1.00
	348	...	S34800	18Cr–10Ni–Cb	8	(9)(10)	75	30	1.00
	348H	...	S34809	18Cr–10Ni–Cb	8	...	75	30	1.00
	348H	...	S34809	18Cr–10Ni–Cb	8	(9)	75	30	1.00
Ferritic/Martensitic									
A 479	XM-27	...	S44627	27Cr–1Mo	10I	(2)	65	40	1.00
Ferritic/Austenitic									
A 479	S31803	...	S31803	22Cr–5.5Ni–3Mo–N	10H	(1)(33)(34)	90	65	1.00

GENERAL NOTES:

(a) The tabulated specifications are ANSI/ASTM or ASTM. For ASME Boiler and Pressure Vessel Code applications, see related specifications in Section II of the ASME Code.

(b) The stress values in this Table may be interpolated to determine values for intermediate temperatures.

(c) The P-Numbers indicated in this Table are identical to those adopted by the ASME Boiler and Pressure Vessel Code. Qualification of welding procedures, welders, and welding operators is required and shall comply with the ASME Boiler and Pressure Vessel Code, Section IX, except as modified by para. 127.5.

(d) Tensile strengths and allowable stresses shown in "ksi" are "thousands of pounds per square inch."

(e) The materials listed in this Table shall not be used at design temperatures above those for which allowable stress values are given herein or in Table A-8.

(f) The tabulated stress values are $S \times E$ (weld joint efficiency factor) or $S \times F$ (material quality factor), as applicable. Weld joint efficiency factors are shown in Table 102.4.3.

(g) Pressure-temperature ratings of piping components, as published in standards referenced in this Code, may be used for components meeting the requirements of those standards. The allowable stress values given in this Table are for use in designing piping components which are not manufactured in accordance with referenced standards.

(h) The tabulated stress values that are shown in italics are at temperatures in the range where creep and stress rupture strength govern the selection of stresses.

NOTES:

(1) THIS MATERIAL IS NOT ACCEPTABLE FOR USE ON BOILER EXTERNAL PIPING — SEE FIGS. 100.1.2(A) AND (B).

(2) Use of this material at temperatures above 650°F is not approved because of the possibility of temper embrittlement.

(3) This steel may be expected to develop embrittlement at room temperature after service at temperatures above 700°F. Consequently, its use at higher temperatures is not recommended unless due caution is observed.

(4) For fittings made from A 182 forgings over 5 in. in thickness, the allowable stress values tabulated shall be reduced by the ratio of 70 divided by 75.

(5) The material quality factors and allowable stress values for these materials may be increased in accordance with para. 102.4.6.

(6) Tensile strengths in parentheses are expected minimum values.

(7) See MSS SP-43 for requirements for lightweight stainless steel fittings. MSS SP-43 Schedule 5S fittings shall not be used for design temperatures above 400°F. MSS SP-43 Schedule 10S fittings shall not be used for design temperatures above 750°F.

(8) The material quality factor for centrifugally cast pipe (0.85) is based on all surfaces being machined after heat treatment. The surface finish, after machining, shall be 250 μin. arithmetic average deviation or smoother.

Table A-3 Stainless Steels (Cont'd)

(07)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																			
−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1,000	1,050	1,100	1,150	1,200	Type or Grade	Spec. No.
																		Bar (Cont'd) Austenitic (Cont'd)	
20.0	18.4	17.1	16.0	15.0	14.3	14.0	13.8	13.7	13.6	13.5	13.4	13.4	13.4	*12.1*	*9.1*	*6.1*	*4.4*	347	A 479
20.0	20.0	18.8	17.8	17.2	16.9	16.8	16.8	16.8	16.8	16.8	16.7	16.6	*16.0*	*12.1*	*9.1*	*6.1*	*4.4*	347	
20.0	18.4	17.1	16.0	15.0	14.3	14.0	13.8	13.7	13.6	13.5	13.4	13.4	13.4	13.4	13.3	*10.5*	*7.9*	347H	
20.0	20.0	18.8	17.8	17.1	16.9	16.8	16.8	16.8	16.8	16.8	16.7	16.6	16.4	16.2	*14.1*	*10.5*	*7.9*	347H	
20.0	18.4	17.1	16.0	15.0	14.3	14.0	13.8	13.7	13.6	13.5	13.4	13.4	13.4	*12.1*	*9.1*	*6.1*	*4.4*	348	A 479
20.0	20.0	18.8	17.8	17.2	16.9	16.8	16.8	16.8	16.8	16.8	16.7	16.6	*16.0*	*12.1*	*9.1*	*6.1*	*4.4*	348	
20.0	18.4	17.1	16.0	15.0	14.3	14.0	13.8	13.7	13.6	13.5	13.4	13.4	13.4	13.4	13.3	*10.5*	*7.9*	348H	
20.0	20.0	18.8	17.8	17.1	16.9	16.8	16.8	16.8	16.8	16.8	16.7	16.6	16.4	16.2	*14.1*	*10.5*	*7.9*	348H	
																		Ferritic/Martensitic	
18.6	18.6	18.3	18.1	18.1	18.1	18.1	...	...	...	...	...	...	...	...	...	...	...	TPXM-27	A 479
																		Ferritic/Austenitic	
25.7	25.7	24.8	23.9	23.3	23.1	...	...	...	...	...	...	...	...	...	...	...	...	S31803	A 479

NOTES (Cont'd):

(9) Due to relatively low yield strength of these materials, these higher allowable stress values were established at temperatures where the short time tensile properties govern to permit the use of these alloys where slightly greater deformation is acceptable. These stress values exceed 67% but do not exceed 90% of the yield strength at temperature. Use of these stress values may result in dimensional changes due to permanent strain. These values should not be used for the flanges of gasketed joints or other applications where slight amounts of distortion can cause leakage or malfunction.

(10) The allowable stress values tabulated for temperatures over 1,000°F apply only if the carbon content of the material is 0.04% or higher.

(11) The allowable stress values tabulated for temperatures over 1,000°F apply only if the material is heat treated by heating to a minimum temperature of 1,900°F and quenching in water or rapidly cooling by other means.

(12) These allowable stress values apply to forgings over 5 in. in thickness.

(13) The allowable stress values tabulated for temperatures over 800°F apply only if the carbon content of the material is 0.04% or higher.

(14) These allowable stress values shall be used only when the grain size of the material is ASTM No. 6 or coarser.

(15) These allowable stress values shall be used when the grain size of the material is finer than ASTM No. 6 or when the grain size has not been determined.

(16) These stress values are established from a consideration of strength only and will be satisfactory for average service. For bolted joints, where freedom from leakage over a long period of time without retightening is required, lower stress values may be necessary as determined from the relative flexibility of the flange and bolts and corresponding relaxation properties.

(17) This is a product specification. Allowable stress values are not necessary. Limitations on metal temperature for materials covered by this specification for use under B31.1 are:

Grade 6 and 8F	−20°F to 800°F
Grades 8, 8C, 8M, and 8T	−20°F to 1,200°F

(18) The hardness of this material, under the thread roots, shall not exceed Rockwell C35. The hardness shall be measured on a flat area, at least $\frac{1}{8}$ in. across, prepared by removing thread. No more material than necessary shall be removed to prepare the flat area. Hardness measurements shall be made at the same frequency as tensile test.

(19) These allowable stress values apply to bolting materials 4 in. in diameter and smaller.

(20) These allowable stress values apply to bolting materials $\frac{3}{4}$ in. in diameter and smaller.

(21) These allowable stress values apply to bolting materials larger than $\frac{3}{4}$ in. but not larger than 1 in. in diameter.

(22) These allowable stress values apply to bolting materials larger than 1 in. but not larger than $1\frac{1}{4}$ in. in diameter.

(23) These allowable stress values apply to bolting materials larger than $1\frac{1}{4}$ in. but not larger than $1\frac{1}{2}$ in. in diameter.

(24) These allowable stress values apply to bolting materials 8 in. in diameter and smaller.

Table A-3 Stainless Steels (Cont'd)

NOTES (Cont'd):

(25) Use of external pressure charts for material in the form of barstock is permitted for stiffening rings only.

(26) At the ferrite levels tabulated below, these materials will have significant reductions in Charpy V-notch toughness values at room temperature and below following service exposure at the indicated temperatures. This reduction indicates the potential for brittle fracture with high rate loading in the presence of sharp notches or cracks.

Ferrite Content	Service Temperature
5% and less	1,100°F and above
10%	900°F and above
15%	800°F and above
20%	700°F and above
25%–30%	600°F and above
35%–40%	500°F and above

(27) The stress values at 1,050°F and above shall be used only when the grain size is ASTM No. 6 or coarser.

(28) These allowable stress values apply to material that has been carbide solution treated.

(29) These allowable stress values apply for single or double butt welded pipe with radiography per para. 136.4.5.

(30) These allowable stress values apply for double butt welded pipe.

(31) These allowable stress values apply for single butt welded pipe.

(32) DELETED

(33) The use of this material is limited to 600°F. This material may be expected to exhibit embrittlement at room temperature after service.

(34) Any heat treatment applied to this material shall be performed at 1,870°F to 2,010°F, followed by a rapid cool. For A 182, A 240, and A 479 material, this is more restrictive than the material specification and shall be met.

(35) Openings ≥ 4 in. shall conform to para. 127.4.8, except that full-penetration welds shall be used and separate reinforcing pads shall not be used.

(36) This steel may be expected to develop embrittlement after exposure to temperatures above 500°F for prolonged times. See ASME Boiler and Pressure Vessel Code, Section II, Part D, Appendix A, A-340 and A-360.

(37) These allowable stress values apply only to forgings 5 in. in thickness and under.

(38) The stress values at temperatures above 1,000°F apply only if Supplementary Requirement S1 has been specified.

(A08) (39) Any heat treatment applied to this material shall be performed at 1,880°F to 2,060°F, followed by a rapid cool.

Table A-4 begins on the next page.

(07)

Table A-4 Nickel and High Nickel Alloys

Spec. No.	UNS Alloy No.	Temper or Condition	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
Seamless Pipe and Tube								
B 161	N02200	Annealed	Ni	41	(1)(5)	55	15	1.00
	N02200	Annealed	Ni	41	(1)(6)	55	12	1.00
	N02200	Str. rel.	Ni	41	(1)	65	40	1.00
B 161	N02201	Annealed	Ni–Low C	41	(1)(5)	50	12	1.00
	N02201	Annealed	Ni–Low C	41	(1)(6)	50	10	1.00
	N02201	Str. rel.	Ni–Low C	41	(1)	60	30	1.00
B 163	N08800	Annealed	Ni–Cr–Fe	45	(1)(7)	75	30	1.00
	N08800	Annealed	Ni–Cr–Fe	45	(1)(2)(7)	75	30	1.00
	N08810	Annealed	Ni–Cr–Fe	45	(1)	65	25	1.00
	N08810	Annealed	Ni–Cr–Fe	45	(1)(2)	65	25	1.00
B 165	N04400	Annealed	Ni–Cu	42	(1)(5)	70	28	1.00
	N04400	Annealed	Ni–Cu	42	(1)(6)	70	25	1.00
	N04400	Str. rel.	Ni–Cu	42	(1)(2)(3)	85	35	1.00
B 167	N06600	H.F./ann.	Ni–Cr–Fe	43	(1)(5)	80	30	1.00
	N06600	H.F./ann.	Ni–Cr–Fe	43	(1)(2)(5)	75	30	1.00
	N06600	H.F./ann.	Ni–Cr–Fe	43	(1)(6)	75	25	1.00
	N06600	H.F./ann.	Ni–Cr–Fe	43	(1)(2)(6)	80	25	1.00
B 167	N06600	C.D./ann.	Ni–Cr–Fe	43	(1)(5)	80	35	1.00
	N06600	C.D./ann.	Ni–Cr–Fe	43	(1)(2)(5)	80	35	1.00
	N06600	C.D./ann.	Ni–Cr–Fe	43	(1)(6)	80	30	1.00
	N06600	C.D./ann.	Ni–Cr–Fe	43	(1)(2)(6)	80	30	1.00
B 167	N06617	Annealed	52Ni–22Cr–13Co–9Mo	43	(1)(7)	95	35	1.00
	N06617	Annealed	52Ni–22Cr–13Co–9Mo	43	(1)(2)(7)	95	35	1.00
B 407	N08800	C.D./ann.	Ni–Cr–Fe	45	(7)	75	30	1.00
	N08800	C.D./ann.	Ni–Cr–Fe	45	(2)(7)	75	30	1.00
	N08810	Annealed	Ni–Cr–Fe	45	(7)	65	25	1.00
	N08810	Annealed	Ni–Cr–Fe	45	(2)(7)	65	25	1.00
B 423	N08825	C.W./ann.	Ni–Fe–Cr–Mo–Cu	45	(1)(7)	85	35	1.00
	N08825	C.W./ann.	Ni–Fe–Cr–Mo–Cu	45	(1)(2)(7)	85	35	1.00
B 444	N06625	Sol. ann.	Ni–Cr–Mo–Cb	43	(1)(14)(18)	100	40	1.00
	N06625	Annealed	Ni–Cr–Mo–Cb	43	(1)(2)(14)	120	60	1.00
B 622	N06022	Sol. ann.	Ni–Mo–Cr–Low C	44	(1)(12)	100	45	1.00
	N06022	Sol. ann.	Ni–Mo–Cr–Low C	44	(1)(2)(12)	100	45	1.00
	N10276	Sol. ann.	Low C–Ni–Mo–Cr	43	(1)(12)	100	41	1.00
	N10276	Sol. ann.	Low C–Ni–Mo–Cr	43	(1)(2)(12)	100	41	1.00
	R30556	Annealed	Ni–Fe–Cr–Co–Mo–W	45	(1)	100	45	1.00
	R30556	Annealed	Ni–Fe–Cr–Co–Mo–W	45	(1)(2)	100	45	1.00
B 677	N08925	Annealed	Ni–Fe–Cr–Mo–Cu–Low C	45	(1)	87	43	1.00
	N08925	Annealed	Ni–Fe–Cr–Mo–Cu–Low C	45	(1)(2)	87	43	1.00
	N08926	Annealed	Ni–Fe–Cr–Mo–Cu–N–Low C	45	(1)(19)(20)	94	43	1.00
	N08926	Annealed	Ni–Fe–Cr–Mo–Cu–N–Low C	45	(1)(2)(19)(20)	94	43	1.00

Table A-4 Nickel and High Nickel Alloys

(07)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																			
−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1,000	1,050	1,100	1,150	1,200	UNS Alloy No.	Spec. No.
Seamless Pipe and Tube																			
10.0	10.0	10.0	10.0	10.0	10.0	...	...	...	...	...	...	...	...	...	...	...	...	N02200	B 161
8.0	8.0	8.0	8.0	8.0	8.0	...	...	...	...	...	...	...	...	...	...	...	...	N02200	
18.6	18.6	18.6	18.6	18.3	17.7	...	...	...	...	...	...	...	...	...	...	...	...	N02200	
8.0	7.7	7.5	7.5	7.5	7.5	7.5	7.4	7.4	*7.2*	*5.8*	*4.5*	*3.7*	*3.0*	*2.4*	*2.0*	*1.5*	*1.2*	N02201	B 161
6.7	6.4	6.3	6.2	6.2	6.2	6.2	6.2	6.1	6.0	*5.8*	*4.5*	*3.7*	*3.0*	*2.4*	*2.0*	*1.5*	*1.2*	N02201	
17.1	17.1	17.0	17.0	16.8	16.3	...	...	...	...	...	...	...	...	...	...	...	...	N02201	
20.0	18.5	17.8	17.2	16.8	16.3	16.1	15.9	15.7	15.5	15.3	15.1	14.9	14.7	14.5	*13.0*	*9.8*	*6.6*	N08800	B 163
20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	19.9	*17.0*	*13.0*	*9.8*	*6.6*	N08800	
16.7	15.4	14.4	13.6	12.9	12.2	11.9	11.6	11.4	11.1	10.9	10.7	10.5	10.4	10.2	10.0	*9.3*	*7.4*	N08810	
16.7	16.7	16.7	16.7	16.7	16.7	16.1	15.7	15.3	15.0	14.7	14.5	14.2	14.0	13.8	11.6	*9.3*	*7.4*	N08810	
18.7	16.4	15.2	14.7	14.7	14.7	14.7	14.6	14.5	14.3	*11.0*	*8.0*	...	...	...	...	...	...	N04400	B 165
16.7	14.6	13.6	13.2	13.1	13.1	13.1	13.0	12.9	12.7	*11.0*	*8.0*	...	...	...	...	...	...	N04400	
24.3	24.3	24.3	24.3	24.3	...	...	...	...	...	...	...	...	...	...	...	...	...	N04400	
20.0	19.1	18.3	17.5	16.8	16.2	15.9	15.7	15.5	15.2	15.1	14.9	*10.6*	*7.0*	*4.5*	*3.0*	*2.2*	*2.0*	N06600	B 167
20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	*16.0*	*10.6*	*7.0*	*4.5*	*3.0*	*2.2*	*2.0*	N06600	
16.7	15.9	15.2	14.6	14.0	13.5	13.3	13.1	12.9	12.7	12.5	12.4	*10.6*	*7.0*	*4.5*	*3.0*	*2.2*	*2.0*	N06600	
16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7	*16.0*	*10.6*	*7.0*	*4.5*	*3.0*	*2.2*	*2.0*	N06600	
22.9	21.3	20.8	20.5	20.2	19.9	19.8	19.6	19.4	19.1	18.7	*16.0*	*10.6*	*7.0*	*4.5*	*3.0*	*2.2*	*2.0*	N06600	B 167
22.9	22.9	22.9	22.9	22.9	22.9	22.9	22.9	22.9	22.9	22.4	*16.0*	*10.6*	*7.0*	*4.5*	*3.0*	*2.2*	*2.0*	N06600	
20.0	19.1	18.3	17.5	16.8	16.2	15.9	15.7	15.5	15.2	15.1	14.9	*10.6*	*7.0*	*4.5*	*3.0*	*2.2*	*2.0*	N06600	
20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	*16.0*	*10.6*	*7.0*	*4.5*	*3.0*	*2.2*	*2.0*	N06600	
23.3	20.8	19.2	18.1	17.2	16.6	16.4	16.2	16.0	15.9	15.8	15.7	15.6	15.5	15.4	15.4	15.3	15.3	N06617	B 167
23.3	23.3	23.3	23.3	23.3	22.5	22.1	21.9	21.7	21.5	21.3	21.2	21.0	20.9	20.9	20.8	20.7	18.1	N06617	
20.0	18.5	17.8	17.2	16.8	16.3	16.1	15.9	15.7	15.5	15.3	15.1	14.9	14.7	14.5	*13.0*	*9.8*	*6.6*	N08800	B 407
20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	19.9	*17.0*	*13.0*	*9.8*	*6.6*	N08800	
16.7	15.4	14.4	13.6	12.9	12.2	11.9	11.6	11.4	11.1	10.9	10.7	10.5	10.4	10.2	10.0	*9.3*	*7.4*	N08810	
16.7	16.7	16.7	16.7	16.7	16.5	16.1	15.7	15.3	15.0	14.7	14.5	14.2	14.0	13.8	*11.6*	*9.3*	*7.4*	N08810	
23.3	21.4	20.3	19.4	18.5	17.8	17.5	17.3	17.2	17.0	...	...	...	...	...	...	...	...	N08825	B 423
23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.2	23.0	...	...	...	...	...	...	...	...	N08825	
26.7	24.9	23.6	22.6	21.8	21.1	20.8	20.6	20.3	20.1	20.0	19.8	19.7	19.5	19.4	19.4	19.3	19.3	N06625	B 444
34.3	34.3	34.3	33.6	32.9	32.4	32.1	31.8	31.5	31.2	30.9	30.6	30.3	29.9	29.5	29.0	*21.0*	*13.2*	N06625	
28.6	26.7	24.6	22.9	21.5	20.4	20.0	19.6	19.3	19.0	...	...	...	...	...	...	...	...	N06022	B 622
28.6	28.6	28.2	27.2	26.5	26.0	25.8	25.6	25.4	25.3	...	...	...	...	...	...	...	...	N06022	
27.3	24.9	23.0	21.3	19.9	18.8	18.2	17.8	17.4	17.1	16.9	16.7	16.6	16.5	...	...	...	...	N10276	
27.3	27.3	27.3	27.3	26.9	25.2	24.6	24.0	23.5	23.1	22.8	22.6	22.4	22.3	...	...	...	...	N10276	
28.6	25.6	23.1	21.3	20.1	19.3	18.9	18.7	18.4	18.2	18.0	17.8	17.6	17.5	17.3	17.1	16.9	13.6	R30556	
28.6	28.6	28.0	27.1	26.4	26.0	25.6	25.2	24.9	24.6	24.3	24.1	23.8	23.6	23.3	21.2	17.0	13.6	R30556	
24.9	23.2	21.3	19.8	18.3	17.3	17.0	16.9	16.9	16.9	...	...	...	...	...	...	...	...	N08925	B 677
24.9	24.9	23.9	23.0	22.1	21.4	21.1	20.8	20.4	20.1	...	...	...	...	...	...	...	...	N08925	
26.9	24.1	21.5	19.7	18.7	18.0	17.7	17.5	17.4	...	...	...	...	...	...	...	...	...	N08926	
26.9	26.9	26.2	24.8	23.7	22.8	22.4	22.0	21.6	...	...	...	...	...	...	...	...	...	N08926	

(07) Table A-4 Nickel and High Nickel Alloys (Cont'd)

	Spec. No.	UNS Alloy No.	Temper or Condition	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
	Seamless Pipe and Tube (Cont'd)								
(A08)	B 690	N08367	Sol. ann.	Fe–Ni–Cr–Mo–Cu–N	45	(1)(8)(22)	95	45	1.00
(A08)		N08367	Sol. ann.	Fe–Ni–Cr–Mo–Cu–N	45	(1)(2)(8)(22)	95	45	1.00
(A08)		N08367	Sol. ann.	Fe–Ni–Cr–Mo–Cu–N	45	(1)(21)	100	45	1.00
(A08)		N08367	Sol. ann.	Fe–Ni–Cr–Mo–Cu–N	45	(1)(2)(21)	100	45	1.00
	B 729	N08020	Annealed	Ni–Fe–Cr–Mo–Cu–Cb	45	(1)	80	35	1.00
		N08020	Annealed	Ni–Fe–Cr–Mo–Cu–Cb	45	(1)(2)	80	35	1.00
	Welded Pipe and Tube								
	B 464	N08020	Annealed	Ni–Fe–Cr–Mo–Cu–Cb	45	(1)	80	35	0.85
		N08020	Annealed	Ni–Fe–Cr–Mo–Cu–Cb	45	(1)(2)	80	35	0.85
	B 468	N08020	Annealed	Ni–Fe–Cr–Mo–Cu–Cb	45	(1)	80	35	0.85
		N08020	Annealed	Ni–Fe–Cr–Mo–Cu–Cb	45	(1)(2)	80	35	0.85
	B 546	N06617	Annealed	52Ni–22Cr–13Co–9Mo	43	(1)(7)	95	35	0.85
		N06617	Annealed	52Ni–22Cr–13Co–9Mo	43	(1)(2)(7)	95	35	0.85
	B 619	N06022	Sol. ann.	Ni–Mo–Cr–Low C	44	(1)(12)	100	45	0.85
		N06022	Sol. ann.	Ni–Mo–Cr–Low C	44	(1)(2)(12)	100	45	0.85
		N10276	Sol. ann.	Low C–Ni–Mo–Cr	43	(1)(12)	100	41	0.85
		N10276	Sol. ann.	Low C–Ni–Mo–Cr	43	(1)(2)(12)	100	41	0.85
		R30556	Annealed	Ni–Fe–Cr–Co–Mo–W	45	(1)	100	45	0.85
		R30556	Annealed	Ni–Fe–Cr–Co–Mo–W	45	(1)(2)	100	45	0.85
	B 626	N06022	Sol. ann.	Ni–Mo–Cr–Low C	44	(1)(12)	100	45	0.85
		N06022	Sol. ann.	Ni–Mo–Cr–Low C	44	(1)(2)(12)	100	45	0.85
		N10276	Sol. ann.	Low C–Ni–Mo–Cr	43	(1)(12)	100	41	0.85
		N10276	Sol. ann.	Low C–Ni–Mo–Cr	43	(1)(2)(12)	100	41	0.85
		R30556	Annealed	Ni–Fe–Cr–Co–Mo–W	45	(1)	100	45	0.85
		R30556	Annealed	Ni–Fe–Cr–Co–Mo–W	45	(1)(2)	100	45	0.85
	B 673	N08925	Annealed	Ni–Fe–Cr–Mo–Cu–Low C	45	(1)	87	43	0.85
		N08925	Annealed	Ni–Fe–Cr–Mo–Cu–Low C	45	(1)(2)	87	43	0.85
		N08926	Annealed	Ni–Fe–Cr–Mo–Cu–N–Low C	45	(1)(19)(20)	94	43	0.85
		N08926	Annealed	Ni–Fe–Cr–Mo–Cu–N–Low C	45	(1)(2)(19)(20)	94	43	0.85
	B 674	N08925	Annealed	Ni–Fe–Cr–Mo–Cu–Low C	45	(1)	87	43	0.85
		N08925	Annealed	Ni–Fe–Cr–Mo–Cu–Low C	45	(1)(2)	87	43	0.85
		N08926	Annealed	Ni–Fe–Cr–Mo–Cu–N–Low C	45	(1)(19)(20)	94	43	0.85
		N08926	Annealed	Ni–Fe–Cr–Mo–Cu–N–Low C	45	(1)(2)(19)(20)	94	43	0.85
(A08)	B 675	N08367	Sol. ann.	Fe–Ni–Cr–Mo–Cu–N	45	(1)(8)(22)	95	45	0.85
(A08)		N08367	Sol. ann.	Fe–Ni–Cr–Mo–Cu–N	45	(1)(2)(8)(22)	95	45	0.85
(A08)		N08367	Sol. ann.	Fe–Ni–Cr–Mo–Cu–N	45	(1)(8)(21)	100	45	0.85
(A08)		N08367	Sol. ann.	Fe–Ni–Cr–Mo–Cu–N	45	(1)(2)(8)(21)	100	45	0.85
(A08)	B 676	N08367	Sol. ann.	Fe–Ni–Cr–Mo–Cu–N	45	(1)(8)(22)	95	45	0.85
(A08)		N08367	Sol. ann.	Fe–Ni–Cr–Mo–Cu–N	45	(1)(2)(8)(22)	95	45	0.85
(A08)		N08367	Sol. ann.	Fe–Ni–Cr–Mo–Cu–N	45	(1)(8)(21)	100	45	0.85
(A08)		N08367	Sol. ann.	Fe–Ni–Cr–Mo–Cu–N	45	(1)(2)(8)(21)	100	45	0.85

Table A-4 Nickel and High Nickel Alloys (Cont'd)

(07)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																				
−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1,000	1,050	1,100	1,150	1,200	UNS Alloy No.	Spec. No.	
																		Seamless Pipe and Tube (Cont'd)		
27.1	26.2	23.8	21.9	20.5	19.4	19.0	18.6	18.3	18.0	...	...	...	...	...	...	...	...	N08367	B 690	**(A08)**
27.1	27.1	25.7	24.6	23.8	23.3	23.1	22.9	22.8	22.6	...	...	...	...	...	...	...	...	N08367		**(A08)**
28.6	26.2	23.8	21.9	20.5	19.4	19.0	18.6	18.3	18.0	...	...	...	...	...	...	...	...	N08367		**(A08)**
28.6	28.6	27.0	25.8	25.0	24.5	24.3	24.1	24.0	23.8	...	...	...	...	...	...	...	...	N08367		**(A08)**
22.9	20.6	19.7	18.9	18.2	17.7	17.5	17.4	17.2	16.8	...	...	...	...	...	...	...	...	N08020	B 729	
22.9	22.9	22.6	22.2	22.1	22.1	22.0	21.9	21.8	21.8	...	...	...	...	...	...	...	...	N08020		
																		Welded Pipe and Tube		
19.4	17.5	16.7	16.1	15.5	15.0	14.9	14.8	14.6	14.3	...	...	...	...	...	...	...	...	N08020	B 464	
19.4	19.4	19.2	18.8	18.8	18.8	18.7	18.6	18.5	18.5	...	...	...	...	...	...	...	...	N08020		
19.4	17.5	16.7	16.1	15.5	15.0	14.9	14.8	14.6	14.3	...	...	...	...	...	...	...	...	N08020	B 468	
19.4	19.4	19.2	18.8	18.8	18.8	18.7	18.6	18.5	18.5	...	...	...	...	...	...	...	...	N08020		
19.8	17.7	16.3	15.4	14.6	14.1	13.9	13.8	13.6	13.5	13.4	13.3	13.3	13.2	13.1	13.1	13.0	13.0	N06617	B 546	
19.8	19.8	19.8	19.8	19.8	19.1	18.8	18.6	18.4	18.3	18.1	18.0	17.9	17.8	17.8	17.7	17.6	15.4	N06617		
24.3	22.7	20.9	19.4	18.3	17.4	17.0	16.7	16.4	16.2	...	...	...	...	...	...	...	...	N06022	B 619	
24.3	22.7	20.9	19.4	18.3	17.4	17.0	16.7	16.4	16.2	...	...	...	...	...	...	...	...	N06022		
23.2	21.2	19.6	18.1	16.9	16.0	15.5	15.1	14.8	14.5	14.4	14.2	14.1	14.0	...	...	...	...	N10276		
23.2	23.2	23.2	23.2	22.9	21.4	20.9	20.4	20.0	19.6	19.4	19.2	19.0	19.0	...	...	...	...	N10276		
24.3	21.8	19.6	18.1	17.1	16.4	16.1	15.9	15.7	15.5	15.3	15.2	15.0	14.8	14.7	14.5	14.4	11.6	R30556		
24.3	24.3	23.8	23.0	22.5	22.1	21.7	21.4	21.1	20.9	20.7	20.5	20.2	20.0	19.8	18.0	14.4	11.6	R30556		
24.3	24.3	23.9	23.1	22.6	22.1	21.9	21.8	21.6	21.5	...	...	...	...	...	...	...	...	N06022	B 626	
24.3	24.3	23.9	23.1	22.6	22.1	21.9	21.8	21.6	21.5	...	...	...	...	...	...	...	...	N06022		
23.2	21.2	19.6	18.1	16.9	16.0	15.5	15.1	14.8	14.5	14.4	14.2	14.1	14.0	...	...	...	...	N10276		
23.2	23.2	23.2	23.2	22.9	21.4	20.9	20.4	20.0	19.6	19.4	19.2	19.0	19.0	...	...	...	...	N10276		
24.3	21.8	19.6	18.1	17.1	16.4	16.1	15.9	15.7	15.5	15.3	15.2	15.0	14.8	14.7	14.5	14.4	11.6	R30556		
24.3	24.3	23.8	23.0	22.5	22.1	21.7	21.4	21.1	20.9	20.7	20.5	20.2	20.0	19.8	18.0	14.4	11.6	R30556		
21.1	19.7	18.1	16.8	15.6	14.7	14.4	14.4	14.4	14.4	...	...	...	...	...	...	...	...	N08925	B 673	
21.1	21.1	20.4	19.5	18.8	18.2	17.9	17.7	17.4	17.0	...	...	...	...	...	...	...	...	N08925		
22.9	20.5	18.3	16.7	15.9	15.3	15.0	14.9	14.8	...	...	...	...	...	...	...	...	...	N08926		
22.9	22.9	22.3	21.1	20.1	19.4	19.0	18.7	18.4	...	...	...	...	...	...	...	...	...	N08926		
21.1	19.7	18.1	16.8	15.6	14.7	14.4	14.4	14.4	14.4	...	...	...	...	...	...	...	...	N08925	B 674	
21.1	21.1	20.4	19.5	18.8	18.2	17.9	17.7	17.4	17.0	...	...	...	...	...	...	...	...	N08925		
22.9	20.5	18.3	16.7	15.9	15.3	15.0	14.9	14.8	...	...	...	...	...	...	...	...	...	N08926		
22.9	22.9	22.3	21.1	20.1	19.4	19.0	18.7	18.4	...	...	...	...	...	...	...	...	...	N08926		
23.1	22.2	20.2	18.7	17.4	16.5	16.1	15.8	15.5	15.3	...	...	...	...	...	...	...	...	N08367	B 675	**(A08)**
23.1	23.1	21.8	20.9	20.2	19.8	19.6	19.5	19.4	19.2	...	...	...	...	...	...	...	...	N08367		**(A08)**
24.3	22.2	20.2	18.7	17.4	16.5	16.1	15.8	15.5	15.3	...	...	...	...	...	...	...	...	N08367		**(A08)**
24.3	24.3	23.0	22.0	21.3	20.8	20.7	20.5	20.4	20.2	...	...	...	...	...	...	...	...	N08367		**(A08)**
23.1	22.2	20.2	18.7	17.4	16.5	16.1	15.8	15.5	15.3	...	...	...	...	...	...	...	...	N08367	B 676	**(A08)**
23.1	23.1	21.8	20.9	20.2	19.8	19.6	19.5	19.4	19.2	...	...	...	...	...	...	...	...	N08367		**(A08)**
24.3	22.2	20.2	18.7	17.4	16.5	16.1	15.8	15.5	15.3	...	...	...	...	...	...	...	...	N08367		**(A08)**
24.3	24.3	23.0	22.0	21.3	20.8	20.7	20.5	20.4	20.2	...	...	...	...	...	...	...	...	N08367		**(A08)**

(07) Table A-4 Nickel and High Nickel Alloys (Cont'd)

	Spec. No.	UNS Alloy No.	Temper or Condition	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
	Welded Pipe and Tube (Cont'd)								
	B 704	N06625	Annealed	Ni–Cr–Mo–Cb	43	(1)(14)	120	60	0.85
	B 705	N06625	Annealed	Ni–Cr–Mo–Cb	43	(1)(14)	120	60	0.85
(A08)	B 804	N08367	Sol. ann.	Fe–Ni–Cr–Mo–Cu–N	45	(1)(8)	95	45	0.85
(A08)		N08367	Sol. ann.	Fe–Ni–Cr–Mo–Cu–N	45	(1)(2)(8)	95	45	0.85
(A08)		N08367	Sol. ann.	Fe–Ni–Cr–Mo–Cu–N	45	(1)(8)(21)	100	45	0.85
(A08)		N08367	Sol. ann.	Fe–Ni–Cr–Mo–Cu–N	45	(1)(2)(8)(21)	100	45	0.85
	Plate, Sheet, and Strip								
	B 168	N06600	Annealed	Ni–Cr–Fe	43	(1)	80	35	1.00
		N06600	Annealed	Ni–Cr–Fe	43	(1)(2)	80	35	1.00
		N06600	Hot rolled	Ni–Cr–Fe	43	(1)(4)	85	35	1.00
		N06600	Hot rolled	Ni–Cr–Fe	43	(1)(2)(4)	85	35	1.00
	B 168	N06617	Annealed	52Ni–22Cr–13Co–9Mo	43	(1)(7)	95	35	1.00
		N06617	Annealed	52Ni–22Cr–13Co–9Mo	43	(1)(2)(7)	95	35	1.00
	B 409	N08800	Annealed	Ni–Cr–Fe	45	(4)(7)	75	30	1.00
		N08800	Annealed	Ni–Cr–Fe	45	(2)(4)(7)	75	30	1.00
		N08810	Annealed	Ni–Cr–Fe	45	(4)(7)	65	25	1.00
		N08810	Annealed	Ni–Cr–Fe	45	(2)(4)(7)	65	25	1.00
	B 424	N08825	Annealed	Ni–Fe–Cr–Mo–Cu	45	(1)(7)	85	35	1.00
		N08825	Annealed	Ni–Fe–Cr–Mo–Cu	45	(1)(2)(7)	85	35	1.00
	B 435	R30556	Annealed	Ni–Fe–Cr–Co–Mo–W	45	(1)	100	45	1.00
		R30556	Annealed	Ni–Fe–Cr–Co–Mo–W	45	(1)(2)	100	45	1.00
	B 443	N06625	Sol. ann.	Ni–Cr–Mo–Cb	43	(1)(14)(18)	100	40	1.00
		N06625	Annealed	Ni–Cr–Mo–Cb	43	(1)(14)	110	55	1.00
		N06625	Annealed	Ni–Cr–Mo–Cb	43	(1)(14)(15)	120	60	1.00
	B 463	N08020	Annealed	Ni–Fe–Cr–Mo–Cu–Cb	45	(1)	80	35	1.00
		N08020	Annealed	Ni–Fe–Cr–Mo–Cu–Cb	45	(1)(12)	80	35	1.00
	B 575	N06022	Sol. ann.	Ni–Mo–Cr–Low C	44	(1)(12)	100	45	1.00
		N06022	Sol. ann.	Ni–Mo–Cr–Low C	44	(1)(2)(12)	100	45	1.00
		N10276	Sol. ann.	Low C–Ni–Mo–Cr	43	(1)(12)	100	41	1.00
		N10276	Sol. ann.	Low C–Ni–Mo–Cr	43	(1)(2)(12)	100	41	1.00
	B 625	N08925	Annealed	Ni–Fe–Cr–Mo–Cu–Low C	45	(1)	87	43	1.00
		N08925	Annealed	Ni–Fe–Cr–Mo–Cu–Low C	45	(1)(2)	87	43	1.00
		N08926	Annealed	Ni–Fe–Cr–Mo–Cu–N–Low C	45	(1)(19)(20)	94	43	1.00
		N08926	Annealed	Ni–Fe–Cr–Mo–Cu–N–Low C	45	(1)(2)(19)(20)	94	43	1.00
(A08)	B 688	N08367	Sol. ann.	Fe–Ni–Cr–Mo–Cu–N	45	(1)(7)(11)(22)	95	45	1.00
(A08)		N08367	Sol. ann.	Fe–Ni–Cr–Mo–Cu–N	45	(1)(2)(7)(11)(22)	95	45	1.00
(A08)		N08367	Sol. ann.	Fe–Ni–Cr–Mo–Cu–N	45	(1)(7)(10)(21)	100	45	1.00
(A08)		N08367	Sol. ann.	Fe–Ni–Cr–Mo–Cu–N	45	(1)(2)(7)(10)(21)	100	45	1.00

Table A-4 Nickel and High Nickel Alloys (Cont'd)

(07)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																				
−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1,000	1,050	1,100	1,150	1,200	UNS Alloy No.	Spec. No.	
																		Welded Pipe and Tube (Cont'd)		
29.1	29.1	29.1	28.5	28.0	27.5	27.3	27.0	26.8	26.5	26.3	26.0	25.7	25.4	25.1	24.7	*17.9*	*11.2*	N06625	B 704	
29.1	29.1	29.1	28.5	28.0	27.5	27.3	27.0	26.8	26.5	26.3	26.0	25.7	25.4	25.1	24.7	*17.9*	*11.2*	N06625	B 705	
23.1	22.2	20.2	18.7	17.4	16.5	16.1	15.8	15.5	15.3	...	...	...	...	...	...	...	...	N08367	B 804	**(A08)**
23.1	23.1	21.8	20.9	20.2	19.8	19.6	19.5	19.4	19.2	...	...	...	...	...	...	...	...	N08367		**(A08)**
24.3	22.2	20.2	18.7	17.4	16.5	16.1	15.8	15.5	15.3	...	...	...	...	...	...	...	...	N08367		**(A08)**
24.3	24.3	23.0	22.0	21.3	20.8	20.7	20.5	20.4	20.2	...	...	...	...	...	...	...	...	N08367		**(A08)**
																		Plate, Sheet, and Strip		
22.9	21.3	20.8	20.5	20.2	19.9	19.8	19.6	19.4	19.1	18.7	*16.0*	*10.6*	*7.0*	*4.5*	*3.0*	*2.2*	*2.0*	N06600	B 168	
22.9	22.9	22.9	22.9	22.9	22.9	22.9	22.9	22.9	22.9	22.4	*16.0*	*10.6*	*7.0*	*4.5*	*3.0*	*2.2*	*2.0*	N06600		
23.3	22.1	21.5	21.3	21.3	21.2	21.1	21.0	20.8	20.5	20.1	19.7	19.3	*14.5*	*10.3*	*7.2*	*5.8*	*5.5*	N06600		
23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	*14.5*	*10.3*	*7.2*	*5.8*	*5.5*	N06600		
23.3	20.8	19.2	18.1	17.2	16.6	16.4	16.2	16.0	15.9	15.8	15.7	15.6	15.5	15.4	15.4	15.3	15.3	N06617	B 168	
23.3	23.3	23.3	23.3	23.3	22.5	22.1	21.9	21.7	21.5	21.3	21.2	21.0	20.9	20.9	20.8	20.7	18.1	N06617		
20.0	18.5	17.8	17.2	16.8	16.3	16.1	15.9	15.7	15.5	15.3	15.1	14.9	14.7	14.5	*13.0*	*9.8*	*6.6*	N08800	B 409	
20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	19.9	*17.0*	*13.0*	*9.8*	*6.6*	N08800		
16.7	15.4	14.4	13.6	12.9	12.2	11.9	11.6	11.4	11.1	10.9	10.7	10.5	10.4	10.2	10.0	*9.3*	*7.4*	N08810		
16.7	16.7	16.7	16.7	16.7	16.5	16.1	15.7	15.3	15.0	14.7	14.5	14.2	14.0	13.8	*11.6*	*9.3*	*7.4*	N08810		
23.3	21.4	20.3	19.4	18.5	17.8	17.5	17.3	17.2	17.0	...	...	...	...	...	...	...	...	N08825	B 424	
23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.2	23.0	...	...	...	...	...	...	...	...	N08825		
28.6	25.6	23.1	21.3	20.1	19.3	18.9	18.7	18.4	18.2	18.0	17.8	17.6	17.5	17.3	17.1	16.9	13.6	R30556	B 435	
28.6	28.6	28.0	27.1	26.4	26.0	25.6	25.2	24.9	24.6	24.3	24.1	23.8	23.6	23.3	21.2	17.0	13.6	R30556		
26.7	24.9	23.6	22.6	21.8	21.1	20.8	20.6	20.3	20.1	20.0	19.8	19.7	19.5	19.4	19.4	19.3	19.3	N06625	B 443	
31.4	31.4	31.4	30.8	30.2	29.7	29.4	29.1	28.9	28.6	28.3	28.0	27.7	27.4	27.0	26.6	*21.0*	*13.2*	N06625		
34.3	34.3	34.3	33.6	32.9	32.4	32.1	31.8	31.5	31.2	30.9	30.6	30.3	29.9	29.5	29.0	*21.0*	*13.2*	N06625		
22.9	20.6	19.7	18.9	18.2	17.7	17.5	17.4	17.2	16.8	...	...	...	...	...	...	...	...	N08020	B 463	
22.9	22.9	22.9	22.6	22.2	22.1	22.1	22.0	21.9	21.8	...	...	...	...	...	...	...	...	N08020		
28.6	28.6	28.2	27.2	26.5	26.0	25.8	25.6	25.4	25.3	...	...	...	...	...	...	...	...	N06022	B 575	
28.6	28.6	28.2	27.2	26.5	26.0	25.8	25.6	25.4	25.3	...	...	...	...	...	...	...	...	N06022		
27.3	24.9	23.0	21.3	19.9	18.8	18.2	17.8	17.4	17.1	16.8	16.7	16.5	16.5	...	...	...	...	N10276		
27.3	27.3	27.3	27.3	26.9	25.2	24.6	24.0	23.5	23.1	22.8	22.6	22.4	22.3	...	...	...	...	N10276		
24.9	23.2	21.3	19.8	18.3	17.3	17.0	16.9	16.9	16.9	...	...	...	...	...	...	...	...	N08925	B 625	
24.9	24.9	23.9	23.0	22.1	21.4	21.1	20.8	20.4	20.1	...	...	...	...	...	...	...	...	N08925		
26.9	24.1	21.5	19.7	18.7	18.0	17.7	17.5	17.4	...	...	...	...	...	...	...	...	...	N08926		
26.9	26.9	26.2	24.8	23.7	22.8	22.4	22.0	21.6	...	...	...	...	...	...	...	...	...	N08926		
27.1	26.2	23.8	21.9	20.5	19.4	19.0	18.6	18.3	18.0	...	...	...	...	...	...	...	...	N08367	B 688	**(A08)**
27.1	27.1	25.7	24.6	23.8	23.3	23.1	22.9	22.8	22.6	...	...	...	...	...	...	...	...	N08367		**(A08)**
28.6	26.2	23.8	21.9	20.5	19.4	19.0	18.6	18.3	18.0	...	...	...	...	...	...	...	...	N08367		**(A08)**
28.6	28.6	27.0	25.8	25.0	24.5	24.3	24.1	24.0	23.8	...	...	...	...	...	...	...	...	N08367		**(A08)**

(07)

Table A-4 Nickel and High Nickel Alloys (Cont'd)

	Spec. No.	UNS Alloy No.	Temper or Condition	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
	Bars, Rods, Shapes, and Forgings								
	B 166	N06617	Annealed	52Ni–22Cr–13Co–9Mo	43	(1)(7)	95	35	1.00
		N06617	Annealed	52Ni–22Cr–13Co–9Mo	43	(1)(2)(7)	95	35	1.00
	B 408	N08800	Annealed	Ni–Cr–Fe	45	(7)	75	30	1.00
		N08800	Annealed	Ni–Cr–Fe	45	(2)(7)	75	30	1.00
		N08810	Annealed	Ni–Cr–Fe	45	(7)	65	25	1.00
		N08810	Annealed	Ni–Cr–Fe	45	(2)(7)	65	25	1.00
	B 425	N08825	Annealed	Ni–Fe–Cr–Mo–Cu	45	(1)(7)	85	35	1.00
		N08825	Annealed	Ni–Fe–Cr–Mo–Cu	45	(1)(2)(7)	85	35	1.00
	B 446	N06625	Sol. ann.	Ni–Cr–Mo–Cb	43	(1)(14)(18)	100	40	1.00
		N06625	Annealed	Ni–Cr–Mo–Cb	43	(1)(2)(14)(16)	110	50	1.00
		N06625	Annealed	Ni–Cr–Mo–Cb	43	(1)(2)(14)(15)(17)	120	60	1.00
	B 462	N08020	Annealed	Ni–Fe–Cr–Mo–Cu–Cb	45	(1)	80	35	1.00
		N08020	Annealed	Ni–Fe–Cr–Mo–Cu–Cb	45	(1)(2)	80	35	1.00
	B 473	N08020	Annealed	Cr–Ni–Fe–Mo–Cu–Cb	45	(1)	80	35	1.00
		N08020	Annealed	Cr–Ni–Fe–Mo–Cu–Cb	45	(1)(2)	80	35	1.00
	B 564	N06617	Annealed	52Ni–22Cr–13Co–9Mo	43	(1)(7)	95	35	1.00
		N06617	Annealed	52Ni–22Cr–13Co–9Mo	43	(1)(2)(7)	95	35	1.00
		N06625	Annealed	Ni–Cr–Mo–Cb	43	(1)(2)(14)(16)	110	50	1.00
		N06625	Annealed	Ni–Cr–Mo–Cb	43	(1)(2)(14)(15)(17)	120	60	1.00
(A08)	B 564	N08367	Sol. ann.	Fe–Ni–Cr–Mo–Cu–N	45	(1)(8)(22)	95	45	1.00
(A08)		N08367	Sol. ann.	Fe–Ni–Cr–Mo–Cu–N	45	(1)(2)(8)(22)	95	45	1.00
		N08800	Annealed	Ni–Cr–Fe	45	(1)	75	30	1.00
		N08800	Annealed	Ni–Cr–Fe	45	(1)(2)	75	30	1.00
		N08810	Annealed	Ni–Cr–Fe	45	(1)	65	25	1.00
		N08810	Annealed	Ni–Cr–Fe	45	(1)(2)	65	25	1.00
	B 572	R30556	Annealed	Ni–Fe–Cr–Co–Mo–W	45	(1)	100	45	1.00
		R30556	Annealed	Ni–Fe–Cr–Co–Mo–W	45	(1)(2)	100	45	1.00
	B 574	N06022	Sol. ann.	Ni–Mo–Cr–Low C	44	(1)(12)	100	45	1.00
		N06022	Sol. ann.	Ni–Mo–Cr–Low C	44	(1)(2)(12)	100	45	1.00
		N10276	Sol. ann.	Low C–Ni–Mo–Cr	43	(1)(12)	100	41	1.00
		N10276	Sol. ann.	Low C–Ni–Mo–Cr	43	(1)(2)(12)	100	41	1.00
	B 649	N08925	Annealed	Ni–Fe–Cr–Mo–Cu–Low C	45	(1)	87	43	1.00
		N08925	Annealed	Ni–Fe–Cr–Mo–Cu–Low C	45	(1)(2)	87	43	1.00
		N08926	Annealed	Ni–Fe–Cr–Mo–Cu–N–Low C	. . .	(1)	94	43	1.00
		N08926	Annealed	Ni–Fe–Cr–Mo–Cu–N–Low C	. . .	(1)(2)	94	43	1.00
(A08)	B 691	N08367	Sol. ann.	Fe–Ni–Cr–Mo–Cu–N	45	(1)(8)(22)	95	45	1.00
(A08)		N08367	Sol. ann.	Fe–Ni–Cr–Mo–Cu–N	45	(1)(2)(8)(22)	95	45	1.00

Table A-4 Nickel and High Nickel Alloys (Cont'd) (07)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																				
−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1,000	1,050	1,100	1,150	1,200	UNS Alloy No.	Spec. No.	
Bars, Rods, Shapes, and Forgings																				
23.3	20.8	19.2	18.1	17.2	16.6	16.4	16.2	16.0	15.9	15.8	15.7	15.6	15.5	15.4	15.4	15.3	15.3	N06617	B 166	
23.3	23.3	23.3	23.3	23.3	22.5	22.1	21.9	21.7	21.5	21.3	21.2	21.0	20.9	20.9	20.8	20.7	18.1	N06617		
20.0	18.5	17.8	17.2	16.8	16.3	16.1	15.9	15.7	15.5	15.3	15.1	14.9	14.7	14.5	*13.0*	*9.8*	*6.6*	N08800	B 408	
20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	19.9	*17.0*	*13.0*	*9.8*	*6.6*	N08800		
16.7	15.4	14.4	13.6	12.9	12.2	11.9	11.6	11.4	11.1	10.9	10.7	10.5	10.4	10.2	10.0	*9.3*	*7.4*	N08810		
16.7	16.7	16.7	16.7	16.7	16.5	16.1	15.7	15.3	15.0	14.7	14.5	14.2	14.0	13.8	*11.6*	*9.3*	*7.4*	N08810		
23.3	21.4	20.3	19.4	18.5	17.8	17.5	17.3	17.2	17.0	...	...	...	...	...	...	...	...	N08825	B 425	
23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.2	23.0	...	...	...	...	...	...	...	...	N08825		
26.7	24.9	23.6	22.6	21.8	21.1	20.8	20.6	20.3	20.1	20.0	19.8	19.7	19.5	19.4	19.4	19.3	19.3	N06625	B 446	
31.4	31.4	31.4	30.8	30.2	29.7	29.4	29.1	28.9	28.6	28.3	28.0	27.7	27.4	27.0	26.6	*21.0*	*13.2*	N06625		
34.3	34.3	34.3	33.6	32.9	32.4	32.1	31.8	31.5	31.2	30.9	30.6	30.3	29.9	29.5	29.0	*21.0*	*13.2*	N06625		
22.9	20.6	19.7	18.9	18.2	17.7	17.5	17.4	17.2	16.8	...	...	...	...	...	...	...	...	N08020	B 462	
22.9	22.9	22.6	22.2	22.1	22.1	22.0	21.9	21.8	21.8	...	...	...	...	...	...	...	...	N08020		
22.9	20.6	19.7	18.9	18.2	17.7	17.5	17.4	17.2	16.8	...	...	...	...	...	...	...	...	N08020	B 473	
22.9	22.9	22.6	22.2	22.1	22.1	22.0	21.9	21.8	21.8	...	...	...	...	...	...	...	...	N08020		
23.3	20.8	19.2	18.1	17.2	16.6	16.4	16.2	16.0	15.9	15.8	15.7	15.6	15.5	15.4	15.4	15.3	15.3	N06617	B 564	
23.3	23.3	23.3	23.3	23.3	22.5	22.1	21.9	21.7	21.5	21.3	21.2	21.0	20.9	20.9	20.8	20.7	18.1	N06617		
31.4	31.4	31.4	30.8	30.2	29.7	29.4	29.1	28.9	28.6	28.3	28.0	27.7	27.4	27.0	26.6	*21.0*	*13.2*	N06625		
34.3	34.3	34.3	33.6	32.9	32.4	32.1	31.8	31.5	31.2	30.9	30.6	30.3	29.9	29.5	29.0	*21.0*	*13.2*	N06625		
27.1	26.2	23.8	21.9	20.5	19.4	19.0	18.6	18.3	18.0	...	...	...	...	...	...	...	...	N08367	B 564	**(A08)**
27.1	27.1	25.7	24.6	23.8	23.3	23.1	22.9	22.8	22.6	...	...	...	...	...	...	...	...	N08367		**(A08)**
20.0	18.5	17.8	17.2	16.8	16.3	16.1	15.9	15.7	15.5	15.3	15.1	14.9	14.7	14.5	*13.0*	*9.8*	*6.6*	N08800		
20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	19.9	*17.0*	*13.0*	*9.8*	*6.6*	N08800		
16.7	15.4	14.4	13.6	12.9	12.2	11.9	11.6	11.4	11.1	10.9	10.7	10.5	10.4	10.2	10.0	*9.3*	*7.4*	N08810		
16.7	16.7	16.7	16.7	16.7	16.5	16.1	15.7	15.3	15.0	14.7	14.5	14.2	14.0	13.8	*11.6*	*9.3*	*7.4*	N08810		
28.6	25.6	23.1	21.3	20.1	19.3	18.9	18.7	18.4	18.2	18.0	17.8	17.6	17.5	17.3	17.1	16.9	13.6	R30556	B 572	
28.6	28.6	28.0	27.1	26.4	26.0	25.6	25.2	24.9	24.6	24.3	24.1	23.8	23.6	23.3	21.2	17.0	13.6	R30556		
28.6	22.9	22.9	22.6	22.2	22.1	22.1	22.0	21.9	21.8	...	...	...	...	...	...	...	...	N06022	B 574	
28.6	28.6	28.2	27.2	26.5	26.0	25.8	25.6	25.4	25.3	...	...	...	...	...	...	...	...	N06022		
27.3	24.9	23.0	21.3	19.9	18.8	18.2	17.8	17.4	17.1	16.9	16.7	16.6	16.5	...	...	...	...	N10276		
27.3	27.3	27.3	27.3	26.9	25.2	24.6	24.0	23.5	23.1	22.8	22.6	22.4	22.3	...	...	...	...	N10276		
24.9	23.2	21.3	19.8	18.3	17.3	17.0	16.9	16.9	16.9	...	...	...	...	...	...	...	...	N08925	B 649	
24.9	24.9	23.9	23.0	22.1	21.4	21.1	20.8	20.4	20.1	...	...	...	...	...	...	...	...	N08925		
26.9	24.1	21.5	19.7	18.7	18.0	17.7	17.5	17.4	...	...	...	...	...	...	...	...	...	N08926		
26.9	26.9	26.2	24.8	23.7	22.8	22.4	22.0	21.6	...	...	...	...	...	...	...	...	...	N08926		
27.1	26.2	23.8	21.9	20.5	19.4	19.0	18.6	18.3	18.0	...	...	...	...	...	...	...	...	N08367	B 691	**(A08)**
27.1	27.1	25.7	24.6	23.8	23.3	23.1	22.9	22.8	22.6	...	...	...	...	...	...	...	...	N08367		**(A08)**

(07) Table A-4 Nickel and High Nickel Alloys (Cont'd)

	Spec. No.	UNS Alloy No.	Temper or Condition	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
	Seamless Fittings								
	B 366	N06022	Sol. ann.	Ni–Mo–Cr–Low C	44	(1)(12)	100	45	1.00
		N06022	Sol. ann.	Ni–Mo–Cr–Low C	44	(1)(2)(12)	100	45	1.00
		N06625	Annealed	Ni–Cr–Mo–Cb	43	(1)(14)	110	50	1.00
	B 366	N08020	Annealed	Cr–Ni–Fe–Mo–Cu–Cb	45	(1)	80	35	. . .
		N08020	Annealed	Cr–Ni–Fe–Mo–Cu–Cb	45	(1)(2)	80	35	. . .
		N08367	Annealed	Ni–Fe–Cr–Mo	45	(1)(8)	95	45	1.00
		N08367	Annealed	Ni–Fe–Cr–Mo	45	(1)(2)(8)	95	45	1.00
	B 366	N08926	Annealed	Ni–Fe–Cr–Mo–Cu–N–Low C	45	(1)	94	43	1.00
		N08926	Annealed	Ni–Fe–Cr–Mo–Cu–N–Low C	45	(1)(2)	94	43	1.00
		N10276	Sol. ann.	Low C–Ni–Mo–Cr	43	(1)(12)	100	41	1.00
		N10276	Sol. ann.	Low C–Ni–Mo–Cr	43	(1)(2)(12)	100	41	1.00
	B 366	R30556	Annealed	Ni–Fe–Cr–Co–Mo–W	45	(1)	100	45	1.00
		R30556	Annealed	Ni–Fe–Cr–Co–Mo–W	45	(1)(2)	100	45	1.00
(A08)	B 462	N08367	Sol. ann.	Fe–Ni–Cr–Mo–Cu–N	45	(1)(8)(22)	95	45	1.00
(A08)		N08367	Sol. ann.	Fe–Ni–Cr–Mo–Cu–N	45	(1)(2)(8)(22)	95	45	1.00
	Welded Fittings								
	B 366	N06022	Sol. ann.	Ni–Mo–Cr–Low C	44	(1)(12)	100	45	0.85
		N06022	Sol. ann.	Ni–Mo–Cr–Low C	44	(1)(2)(12)	100	45	0.85
		N06625	Annealed	Ni–Cr–Mo–Cb	43	(1)(14)	110	50	0.85
		N08020	Annealed	Cr–Ni–Fe–Mo–Cu–Cb	45	(1)	80	35	0.85
		N08020	Annealed	Cr–Ni–Fe–Mo–Cu–Cb	45	(1)(2)	80	35	0.85
(A08)	B 366	N08367	Sol. ann.	Fe–Ni–Cr–Mo–Cu–N	45	(1)(8)(22)	95	45	0.85
(A08)		N08367	Sol. ann.	Fe–Ni–Cr–Mo–Cu–N	45	(1)(2)(8)(22)	95	45	0.85
		N08925	Annealed	Ni–Fe–Cr–Mo–Cu–Low C	45	(1)	87	43	0.85
		N08925	Annealed	Ni–Fe–Cr–Mo–Cu–Low C	45	(1)(2)	87	43	0.85
		N08926	Annealed	Ni–Fe–Cr–Mo–Cu–N–Low C	45	(1)(19)(20)	94	43	0.85
		N08926	Annealed	Ni–Fe–Cr–Mo–Cu–N–Low C	45	(1)(2)(19)(20)	94	43	0.85
	B 366	N10276	Sol. ann.	Low C–Ni–Mo–Cr	43	(1)(12)	100	41	0.85
		N10276	Sol. ann.	Low C–Ni–Mo–Cr	43	(1)(2)(12)	100	41	0.85
		R30556	Annealed	Ni–Fe–Cr–Co–Mo–W	45	(1)(12)	100	45	0.85
		R30556	Annealed	Ni–Fe–Cr–Co–Mo–W	45	(1)(2)(12)	100	45	0.85

Table A-4 Nickel and High Nickel Alloys (Cont'd) (07)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding −20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1,000	1,050	1,100	1,150	1,200	UNS Alloy No.	Spec. No.	
																			Seamless Fittings	
28.6	22.9	22.9	22.6	22.2	22.1	22.1	22.0	21.9	21.8	...	...	...	...	...	...	...	...	N06022	B 366	
28.6	28.6	28.2	27.2	26.5	26.0	25.8	25.6	25.4	25.3	...	...	...	...	...	...	...	...	N06022		
26.7	26.7	26.5	25.8	25.0	24.3	24.1	23.7	23.5	23.3	23.0	22.9	22.8	22.6	22.5	22.4	*17.9*	*11.2*	N06625		
22.9	20.6	19.7	18.9	18.2	17.7	17.5	17.4	17.2	16.8	...	...	...	...	...	...	...	...	N08020	B 366	
22.9	22.9	22.6	22.2	22.1	22.1	22.0	21.9	21.8	21.8	...	...	...	...	...	...	...	...	N08020		
27.1	26.2	23.8	21.9	20.5	19.4	19.0	18.6	18.3	18.0	...	...	...	...	...	...	...	...	N08367		
27.1	27.1	25.7	24.6	23.8	23.3	23.1	22.9	22.8	22.6	...	...	...	...	...	...	...	...	N08367		
26.9	24.1	21.5	19.7	18.7	18.0	17.7	17.5	17.4	...	...	...	...	...	...	...	...	...	N08926	B 366	
26.9	26.9	26.2	24.8	23.7	22.8	22.4	22.0	21.6	...	...	...	...	...	...	...	...	...	N08926		
27.3	24.9	23.0	21.3	19.9	18.8	18.2	17.8	17.4	17.1	16.9	16.7	16.6	16.5	...	...	...	...	N10276		
27.3	27.3	27.3	27.3	26.9	25.2	24.6	24.0	23.5	23.1	22.8	22.6	22.4	22.3	...	...	...	...	N10276		
28.6	25.6	23.1	21.3	20.1	19.3	18.9	18.7	18.4	18.2	18.0	17.8	17.6	17.5	17.3	17.1	16.9	13.6	R30556	B 366	
28.6	28.6	28.0	27.1	26.4	26.0	25.6	25.2	24.9	24.6	24.3	24.1	23.8	23.6	23.3	21.2	17.0	13.6	R30556		
27.1	26.2	23.8	21.9	20.5	19.4	19.0	18.6	18.3	18.0	...	...	...	...	...	...	...	...	N08367	B 462	**(A08)**
27.1	27.1	25.7	24.6	23.8	23.3	23.1	22.9	22.8	22.6	...	...	...	...	...	...	...	...	N08367		**(A08)**
																			Welded Fittings	
24.3	22.7	20.9	19.4	18.3	17.4	17.0	16.7	16.4	16.2	...	...	...	...	...	...	...	...	N06022	B 366	
24.3	24.3	23.9	23.1	22.6	22.1	21.9	21.8	21.6	21.5	...	...	...	...	...	...	...	...	N06022		
31.4	31.4	31.2	30.3	29.4	28.6	28.3	27.9	27.6	27.4	27.1	26.9	26.8	26.6	26.5	26.4	*21.0*	*13.2*	N06625		
22.9	20.6	19.7	18.9	18.2	17.7	17.5	17.4	17.2	16.8	...	...	...	...	...	...	...	...	N08020		
22.9	22.9	22.6	22.2	22.1	22.1	22.0	21.9	21.8	21.8	...	...	...	...	...	...	...	...	N08020		
23.1	22.2	20.2	18.7	17.4	16.5	16.1	15.8	15.5	15.3	...	...	...	...	...	...	...	...	N08367	B 366	**(A08)**
23.1	23.1	21.8	20.9	20.2	19.8	19.6	19.5	19.4	19.2	...	...	...	...	...	...	...	...	N08367		**(A08)**
21.1	19.7	18.1	16.8	15.6	14.7	14.4	14.4	14.4	14.4	...	...	...	...	...	...	...	...	N08925		
21.1	21.1	20.4	19.5	18.8	18.2	17.9	17.7	17.4	17.0	...	...	...	...	...	...	...	...	N08925		
22.9	20.5	18.3	16.7	15.9	15.3	15.0	14.9	14.8	...	...	...	...	...	...	...	...	...	N08926		
22.9	22.9	22.3	21.1	20.1	19.4	19.0	18.7	18.4	...	...	...	...	...	...	...	...	...	N08926		
23.2	21.2	19.6	18.1	16.9	16.0	15.5	15.1	14.8	14.5	14.4	14.2	14.1	14.0	...	...	...	...	N10276	B 366	
23.2	23.2	23.2	23.2	22.9	21.4	20.9	20.4	20.0	19.6	19.4	19.2	19.0	19.0	...	...	...	...	N10276		
24.3	21.8	19.6	18.1	17.1	16.4	16.1	15.9	15.7	15.5	15.3	15.2	15.0	14.8	14.7	14.5	14.4	11.6	R30556		
24.3	24.3	23.8	23.0	22.5	22.1	21.7	21.4	21.1	20.9	20.7	20.5	20.2	20.0	19.8	18.0	14.4	11.6	R30556		

Table A-4 Nickel and High Nickel Alloys (Cont'd)

GENERAL NOTES:

(a) The tabulated specifications are ANSI/ASTM or ASTM. For ASME Boiler and Pressure Vessel Code applications, see related specifications in Section II of the ASME Code.

(b) The stress values in this Table may be interpolated to determine values for intermediate temperatures.

(c) The P-Numbers indicated in this Table are identical to those adopted by the ASME Boiler and Pressure Vessel Code. Qualification of welding procedures, welders, and welding operators is required and shall comply with the ASME Boiler and Pressure Vessel Code, Section IX, except as modified by para. 127.5.

(d) Tensile strengths and allowable stresses shown in "ksi" are "thousands of pounds per square inch."

(e) The materials listed in this table shall not be used at design temperatures above those for which allowable stress values are given herein or in Table A-8.

(f) The tabulated stress values are $S \times E$ (weld joint efficiency factor) or $S \times F$ (material quality factor), as applicable. Weld joint efficiency factors are shown in Table 102.4.3.

(g) Pressure-temperature ratings of piping components, as published in standards referenced in this Code, may be used for components meeting the requirements of those standards. The allowable stress values given in this Table are for use in designing piping components which are not manufactured in accordance with referenced standards.

(h) The y coefficient = 0.4 except where Note (7) applies [see Table 104.1.2(A)].

(i) The tabulated stress values that are shown in italics are at temperatures in the range where creep and stress rupture strength govern the selection of stresses.

NOTES:

(1) THIS MATERIAL IS NOT ACCEPTABLE FOR USE ON BOILER EXTERNAL PIPING — SEE FIGS. 100.1.2(A) AND (B).

(2) Due to the relatively low yield strengths of these materials, these higher allowable stress values were established at temperatures where the short time tensile properties govern to permit the use of these alloys where slightly greater deformation is acceptable. These stress values exceed 67% but do not exceed 90% of the yield strength at temperature. Use of these values may result in dimensional changes due to permanent strain. These values should not be used for flanges of gasketed joints or other applications where slight amounts of distortion can cause leakage or malfunction.

(3) The maximum temperature is limited to 500°F because harder temper adversely affects design stress in the creep rupture temperature range.

(4) These values may be used for plate material only.

(5) These values apply to sizes NPS 5 and smaller.

(6) These values apply to sizes larger than NPS 5.

(7) See Table 104.1.2(A) for y coefficient value.

(8) Heat treatment after forming or welding is neither required nor prohibited. However, if heat treatment is applied, the solution annealing treatment shall consist of heating to a minimum temperature of 2,025°F and then quenching in water or rapidly cooling by other means.

(9) These values apply to thickness less than $^3/_{16}$ in.

(10) These values apply to thickness from $^3/_{16}$ in. up to and including $^3/_4$ in.

(11) These values apply to thickness more than $^3/_4$ in.

(12) All filler metal, including consumable insert material, shall comply with the requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

(13) DELETED

(14) This alloy is subject to severe loss of impact strength at room temperature after exposure in the range of 1,000°F to 1,400°F.

(15) The minimum tensile strength of reduced tension specimens in accordance with QW-462.1 of Section IX shall not be less than 110,000 psi.

(16) These values apply to material with a thickness of greater than 4 in. prior to machining or fabricating.

(17) These values apply to material with a maximum thickness of 4 in. prior to machining or fabricating.

(18) For service at 1,200°F or higher, the deposited weld metal shall be of the same nominal chemistry as the base metal.

(19) Heat treatment after fabrication and forming is neither required nor prohibited. If heat treatment is performed, the material shall be heated for a sufficient time in the range of 2,010°F to 2,100°F followed by quenching in water or rapidly cooled by another means.

(20) Welding electrodes or filler metal used for welding UNS N08926 shall conform to SFA-5.11 ENiCrMo-3 or ENiCrMo-4, or SFA-5.14 ERNiCrMo-3 or ERNiCrMo-4.

(A08) (21) These values apply to thicknesses $^3/_{16}$ in. or less.

(A08) (22) These values apply to thicknesses greater than $^3/_{16}$ in.

Table A-5 Cast Iron

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding							
−20 to 400	450	500	600	650	−20 to 650	Class	Spec. No.
							Gray Cast Iron
2.0	...	...	...	...	...	20	A 48
2.5	...	...	...	...	...	25	
3.0	...	...	...	...	...	30	
3.5	...	...	...	...	...	35	
4.0	...	...	...	...	...	40	
4.5	...	...	...	...	...	45	
5.0	...	...	...	...	...	50	
5.5	...	...	...	...	...	55	
6.0	...	...	...	...	...	60	
2.1	...	...	...	...	...	A	A 126
3.1	...	...	...	...	...	B	
4.1	...	...	...	...	...	C	
2.0	2.0	...	...	...	...	20	A 278
2.5	2.5	...	...	...	...	25	
3.0	3.0	...	...	...	...	30	
3.5	3.5	...	...	...	...	35	
...	...	...	...	...	4.0	40	
...	...	...	...	...	4.5	45	
...	...	...	...	...	5.0	50	
...	...	...	...	...	5.5	55	
...	...	...	...	...	6.0	60	
							Ductile Cast Iron
...	...	...	...	...	9.6	60-40-18	A 395
10.4	10.4	...	...	...	...	65-45-15	
...	...	...	...	...	4.8	60-42-10	A 536
...	...	...	...	...	5.6	70-50-05	

NOTES:

(1) THIS MATERIAL IS NOT ACCEPTABLE FOR BOILER EXTERNAL PIPING — SEE FIGS. 100.1.2(A) AND (B).

(2) Material quality factors are not applicable to these materials.

(3) For saturated steam at 250 psi (406°F), the stress values given at 400°F may be used.

(4) For limitations on the use of this material, see para. 124.4.

(5) This material shall not be used where the design pressure exceeds 250 psig [1 725 kPa (gage)] or where the design temperature exceeds 450°F (230°C).

(6) This material shall not be used for boiler external piping where the design pressure exceeds 350 psig [2 415 kPa (gage)] or where the design temperature exceeds 450°F (230°C).

(7) Piping components conforming to either ASME B16.1 or ASME B16.4 may be used for boiler external piping, subject to all the requirements of the particular standard.

(8) For limitations on the use of this material, see para. 124.6.

Table A-6 Copper and Copper Alloys

	Spec. No.	UNS Alloy No.	Temper or Condition	Size or Thickness, in.	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
	Seamless Pipe and Tube								
	B 42	C10200, C12000, C12200	Annealed	. . .	31	(2)	30	9	1.00
(A08)		C10200, C12000, C12200	Drawn	2 & under	31	(2)(4)	45	40	1.00
(A08)		C10200, C12000, C12200	Drawn	Over 2 to 12	31	(2)(4)	36	30	1.00
	B 43	C23000	Annealed	. . .	31	(2)	40	12	1.00
		C23000	Drawn	. . .	31	(2)(4)	44	18	1.00
	B 68	C10200, C12000, C12200	Annealed	. . .	31	(1)	30	9	1.00
	B 75	C10200, C12000	Annealed	. . .	31	(2)	30	9	1.00
		C10200, C12000	Light drawn	. . .	31	(2)(4)	36	30	1.00
		C10200, C12000	Hard drawn	. . .	31	(2)(4)	45	40	1.00
	B 75	C12200	Annealed	. . .	31	(2)	30	9	1.00
		C12200	Light drawn	. . .	31	(2)(4)	36	30	1.00
		C12200	Hard drawn	. . .	31	(2)(4)	45	40	1.00
	B 88	C10200, C12000, C12200	Annealed	. . .	31	(1)	30	9	1.00
		C10200, C12000, C12200	Drawn	. . .	31	(1)(4)	36	30	1.00
	B 111	C10200, C12000	Light drawn	. . .	31	(1)(3)	36	30	1.00
		C10200, C12000	Hard drawn	. . .	31	(1)(3)	45	40	1.00
		C12200, C14200	Light drawn	. . .	31	(1)(3)	36	30	1.00
		C12200, C14200	Hard drawn	. . .	31	(1)(3)	45	40	1.00
	B 111	C23000	Annealed	. . .	32	(1)	40	12	1.00
		C28000	Annealed	. . .	32	(2)	50	20	1.00
		C44300, C44400, C44500	Annealed	. . .	32	(2)	45	15	1.00
(A08)		C60800	Annealed	. . .	35	(1)	50	19	1.00
	B 111	C68700	Annealed	. . .	32	(1)	50	18	1.00
		C70400	Annealed	. . .	34	(1)	38	12	1.00
		C70400	Light drawn	. . .	34	(1)(4)	40	30	1.00
	B 111	C70600	Annealed	. . .	34	(2)	40	15	1.00
		C71000	Annealed	. . .	34	(2)	45	16	1.00
		C71500	Annealed	. . .	34	(2)	52	18	1.00
(A08)	B 280	C12200	Annealed	. . .	31	(1)	30	9	1.00
		C12200	Drawn	. . .	31	(1)(4)	36	30	1.00
	B 302	C12000, C12200	Drawn	. . .	32	(1)(3)	36	30	1.00
	B 315	C61300, C61400	Annealed	. . .	35	(1)	65	28	1.00
	B 466	C70600	Annealed	. . .	34	(1)	38	13	1.00
(A08)		C71500	Annealed	. . .	34	(1)	50	18	1.00
	Welded Pipe and Tube								
	B 467	C70600	Annealed	$4\frac{1}{2}$ & under	34	(1)	40	15	0.85
		C70600	Annealed	Over $4\frac{1}{2}$	34	(1)	38	13	0.85
		C71500	Annealed	$4\frac{1}{2}$ & under	34	(1)	50	20	0.85
		C71500	Annealed	Over $4\frac{1}{2}$	34	(1)	45	15	0.85
(A08)	B 608	C61300, C61400	Annealed	. . .	35	(1)(6)	70	30	0.80

Table A-6 Copper and Copper Alloys

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																	
−20 to 100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	UNS Alloy No.	Spec. No.	
															Seamless Pipe and Tube		
6.0	5.1	4.9	4.8	4.7	*4.0*	*3.0*	...	...	...	...	...	...	...	...	C10200, C12000, C12200	B 42	
12.9	12.9	12.9	12.9	12.5	11.8	*4.3*	...	...	...	...	...	...	...	...	C10200, C12000, C12200		**(A08)**
10.3	10.3	10.3	10.3	10.0	9.7	9.4	...	...	...	...	...	...	...	...	C10200, C12000, C12200		**(A08)**
8.0	8.0	8.0	8.0	8.0	*7.0*	*5.0*	*2.0*	...	...	...	...	...	...	...	C23000	B 43	
8.0	8.0	8.0	8.0	8.0	*7.0*	*5.0*	*2.0*	...	...	...	...	...	...	...	C23000		
6.0	5.1	4.9	4.8	4.7	*4.0*	*3.0*	...	...	...	...	...	...	...	...	C10200, C12000, C12200	B 68	
6.0	5.1	4.9	4.8	4.7	*4.0*	*3.0*	...	...	...	...	...	...	...	...	C10200, C12000	B 75	
10.3	10.3	10.3	10.3	10.0	9.7	9.4	...	...	...	...	...	...	...	...	C10200, C12000		
12.9	12.9	12.9	12.9	12.5	11.8	*4.3*	...	...	...	...	...	...	...	...	C10200, C12000		
6.0	5.1	4.9	4.8	4.7	*4.0*	*3.0*	...	...	...	...	...	...	...	...	C12200	B 75	
10.3	10.3	10.3	10.3	10.0	9.7	9.4	...	...	...	...	...	...	...	...	C12200		
12.9	12.9	12.9	12.9	12.5	11.8	*4.3*	...	...	...	...	...	...	...	...	C12200		
6.0	5.1	4.9	4.8	4.7	*4.0*	*3.0*	...	...	...	...	...	...	...	...	C10200, C12000, C12200	B 88	
10.3	10.3	10.3	10.3	10.0	9.7	9.4	...	...	...	...	...	...	...	...	C10200, C12000, C12200		
10.3	10.3	10.3	10.3	10.0	9.7	9.4	...	...	...	...	...	...	...	...	C10200, C12000	B 111	
12.9	12.9	12.9	12.9	12.5	11.8	*4.3*	...	...	...	...	...	...	...	...	C10200, C12000		
10.3	10.3	10.3	10.3	10.0	9.7	9.4	...	...	...	...	...	...	...	...	C12200, C14200		
12.9	12.9	12.9	12.9	12.5	11.8	*4.3*	...	...	...	...	...	...	...	...	C12200, C14200		
8.0	8.0	8.0	8.0	8.0	*7.0*	*5.0*	*2.0*	...	...	...	...	...	...	...	C23000	B 111	
13.3	13.3	13.3	13.3	13.3	*10.8*	*5.3*	...	...	...	...	...	...	...	...	C28000		
10.0	10.0	10.0	10.0	10.0	9.8	*3.5*	*2.0*	...	...	...	...	...	...	...	C44300, C44400, C44500		
12.7	12.2	12.2	12.2	12.0	10.0	*6.0*	*4.0*	*2.0*	...	...	...	...	...	...	C60800		**(A08)**
12.0	11.9	11.8	11.7	11.7	*6.5*	*3.3*	*1.8*	...	...	...	...	...	...	...	C68700	B 111	
8.0	8.0	...	...	...	...	...	...	...	...	...	...	...	...	...	C70400		
10.0	10.0	...	...	...	...	...	...	...	...	...	...	...	...	...	C70400		
10.0	9.7	9.5	9.3	9.0	8.8	8.7	8.5	*8.0*	*7.0*	*6.0*	...	...	...	...	C70600	B 111	
10.7	10.6	10.5	10.4	10.2	10.1	9.9	9.6	9.3	*8.9*	*8.4*	*7.7*	*7.0*	...	...	C71000		
12.0	11.6	11.3	11.0	10.8	10.5	10.3	10.1	9.9	*9.8*	*9.6*	*9.5*	*9.4*	...	...	C71500		
6.0	5.1	4.9	4.8	4.7	4.0	3.0	...	...	...	...	...	...	...	...	C12200	B 280	**(A08)**
10.3	10.3	10.3	10.3	10.0	9.7	9.4	...	...	...	...	...	...	...	...	C12200		
10.3	10.3	10.3	10.3	10.0	9.7	9.4	...	...	...	...	...	...	...	...	C12000, C12200	B 302	
18.6	18.6	18.5	18.3	18.2	18.1	17.9	17.5	17.0	...	...	...	...	...	...	C61300, C61400	B 315	
8.7	8.4	8.2	8.0	7.8	7.7	7.5	7.4	7.3	*7.0*	*6.0*	...	...	...	...	C70600	B 466	
12.0	11.6	11.3	11.0	10.8	10.5	10.3	10.1	*9.9*	*9.8*	*9.6*	*9.5*	*9.4*	...	...	C71500		**(A08)**
															Welded Pipe and Tube		
8.5	8.3	8.1	7.9	7.7	7.5	7.4	7.2	*6.3*	*5.7*	*4.3*	...	...	...	...	C70600	B 467	
7.4	7.2	7.0	6.8	6.7	6.5	6.4	6.3	6.2	*5.7*	*4.3*	...	...	...	...	C70600		
11.3	10.9	10.7	10.4	10.2	10.0	9.7	9.6	*9.4*	*9.2*	*9.1*	...	...	...	...	C71500		
8.5	8.2	8.0	7.8	7.6	7.5	7.3	7.2	*7.0*	*6.9*	*6.8*	...	...	...	...	C71500		
16.0	15.9	15.8	15.7	15.6	15.5	15.4	15.1	14.6	...	...	...	...	...	...	C61300, C61400	B 608	**(A08)**

(07)

Table A-6 Copper and Copper Alloys (Cont'd)

	Spec. No.	UNS Alloy No.	Temper or Condition	Size or Thickness, in.	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
	Plate								
(A08)	B 171	C70600	Annealed	2½ & under	34	(1)	40	15	1.00
(A08)		C70600	Hot rolled	2½ & under	34	(1)	40	15	1.00
(A08)		C71500	Annealed	2½ & under	34	(1)	50	20	1.00
(A08)		C71500	Annealed	Over 2½ to 5	34	(1)	45	18	1.00
	Rod and Bar								
(A08)	B 151	C71500	Annealed	Over 1	34	(1)	45	18	1.00
	Die Forgings (Hot Pressed)								
	B 283	C37700	As forged	1½ & under	...	(1)(3)	50	18	1.00
		C37700	As forged	Over 1½	...	(1)(3)	46	15	1.00
	Castings								
	B 61	C92200	As cast	...	...	...	34	16	0.80
	B 62	C83600	As cast	...	...	...	30	14	0.80
(A08)	B 148	C95200	As cast	...	35	(1)	65	25	0.80
(A08)		C95400	As cast	...	35	(1)(5)	75	30	0.80
	B 584	C92200	As cast	...	...	...	34	16	0.80
		C93700	As cast	...	...	(3)	30	12	0.80
		C97600	As cast	...	...	(3)	40	17	0.80
	Bolts, Nuts, and Studs								
	B 150	C61400	HR50	½ & under	...	(1)(3)	80	50	1.00
		C61400	HR50	Over ½ to 1	...	(1)(3)	75	35	1.00
		C61400	HR50	Over 1 to 2	...	(1)(3)	70	32	1.00
		C61400	HR50	Over 2 to 3	...	(1)(3)	70	30	1.00

GENERAL NOTES:

(a) The tabulated specifications are ANSI/ASTM or ASTM. For ASME Boiler and Pressure Vessel Code applications, see related specifications in Section II of the ASME Code.

(b) The stress values in this Table may be interpolated to determine values for intermediate temperatures.

(c) The P-Numbers listed in this Table are identical to those adopted by the ASME Boiler and Pressure Vessel Code. Qualification of welding procedures, welders, and welding operators is required and shall comply with the ASME Boiler and Pressure Vessel Code, Section IX, except as modified by para. 127.5.

(d) Tensile strengths and allowable stresses shown in "ksi" are "thousands of pounds per square inch."

(e) The materials listed in this Table shall not be used at design temperatures above those for which allowable stress values are given. However, for saturated steam at 250 psi (406°F), the allowable stress values given for 400°F may be used.

(f) The tabulated stress values are $S \times E$ (weld joint efficiency factor) or $S \times F$ (material quality factor), as applicable. Weld joint efficiency factors are shown in Table 102.4.3.

(g) Pressure-temperature ratings of piping components, as published in standards referenced in this Code, may be used for components meeting the requirements of those standards. The allowable stress values given in this Table are for use in designing piping components that are not manufactured in accordance with referenced standards.

(h) For limitations on the use of copper and copper alloys for flammable liquids and gases, refer to paras. 122.7, 122.8, and 124.7.

(i) The y coefficient equals 0.4 [see Table 104.1.2(A)].

(j) The tabulated stress values that are shown in italics are at temperatures in the range where creep and stress rupture strength govern the selection of stresses.

Table A-6 Copper and Copper Alloys (07)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																	
−20 to 100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	UNS Alloy No.	Spec. No.	
																Plate	
10.0	9.7	9.5	9.3	9.0	8.8	8.7	8.5	*8.0*	*7.0*	*6.0*	...	...	...	...	C70600	B 171	**(A08)**
10.0	9.7	9.5	9.3	9.0	8.8	8.7	8.5	*8.0*	*7.0*	*6.0*	...	...	...	...	C70600		**(A08)**
13.3	12.9	12.6	12.3	12.0	11.7	11.5	11.2	*11.0*	*10.8*	*10.7*	*10.6*	*10.4*	...	...	C71500		**(A08)**
12.0	11.6	11.3	11.0	10.8	10.5	10.3	10.1	*9.9*	*9.8*	*9.6*	*9.5*	*9.4*	...	...	C71500		**(A08)**
																Rod and Bar	
12.0	11.6	11.3	11.0	10.8	10.5	10.3	10.1	*9.9*	*9.8*	*9.6*	*9.5*	*9.4*	...	...	C71500	B 151	**(A08)**
																Die Forgings (Hot Pressed)	
12.0	11.3	10.8	...	...	...	...	...	...	...	...	...	...	...	...	C37700	B 283	
10.0	9.4	9.0	...	...	...	...	...	...	...	...	...	...	...	...	C37700		
																Castings	
7.8	7.8	7.8	7.8	7.8	7.8	6.6	6.2	5.4	*4.0*	...	...	...	...	...	C92200	B 61	
6.9	6.9	6.9	6.9	6.6	6.5	5.5	5.4	...	...	...	...	...	...	...	C83600	B 62	
13.4	12.6	12.2	11.8	11.6	*11.4*	*11.4*	*11.4*	*11.4*	*9.4*	*5.9*	...	...	...	...	C95200	B 148	**(A08)**
16.0	15.2	15.0	14.8	*14.8*	*14.8*	*14.8*	*12.8*	*11.1*	*8.6*	*6.8*	...	...	...	...	C95400		**(A08)**
7.8	7.8	7.8	7.8	7.8	7.8	6.6	6.2	5.8	*5.0*	...	...	...	...	...	C92200	B 584	
6.9	6.9	5.8	5.4	5.3	5.2	5.1	...	...	...	...	...	...	...	...	C93700		
6.0	5.8	5.6	5.5	5.4	...	...	...	...	...	...	...	...	...	...	C97600		
																Bolts, Nuts, and Studs	
17.5	17.5	17.5	17.5	17.5	17.5	17.2	16.6	16.1	...	...	...	...	...	...	C61400	B 150	
17.5	17.5	17.5	17.5	17.5	17.5	17.2	16.6	16.1	...	...	...	...	...	...	C61400		
17.5	17.5	17.5	17.5	17.5	17.5	17.2	16.6	16.1	...	...	...	...	...	...	C61400		
17.5	17.5	17.5	17.5	17.5	17.5	17.2	16.6	16.1	...	...	...	...	...	...	C61400		

NOTES:

(1) THIS MATERIAL IS NOT ACCEPTABLE FOR USE ON BOILER EXTERNAL PIPING — SEE FIGS. 100.1.2(A) and (B).

(07) (2) This material may be used for Boiler External Piping provided that the nominal size does not exceed 3 in. and the design temperature does not exceed 406°F. This material shall not be used for blowoff or blowdown piping except as permitted in para. 122.1.4. Where threaded brass or copper pipe is used for feedwater piping, it shall have a wall thickness not less than that required for schedule 80 steel pipe of the same nominal size.

(3) Welding or brazing of this material is not permitted.

(4) When this material is used for welded or brazed construction, the allowable stress values used shall not exceed those given for the same material in the annealed condition.

(5) Castings that are welded or repair welded shall be heat treated at 1,150°F–1,200°F, followed by moving-air cooling. The required time at temperature is based on the cross-section thicknesses as follows:
  (*a*) $1\frac{1}{2}$ hr for the first inch or fraction thereof
  (*b*) $\frac{1}{2}$ hr for each additional inch or fraction thereof

(6) Welds must be made by an electric fusion welding process involving the addition of filler metal.

Table A-7 Aluminum and Aluminum Alloys

Spec. No.	UNS Alloy No.	Temper	Size or Thickness, in.	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Drawn Seamless Tube								
B 210	A93003	O	0.010 to 0.500	21	(1)	14	5	1.00
	A93003	H14	0.010 to 0.500	21	(1)(3)	20	17	1.00
	Alclad A93003	O	0.010 to 0.500	21	(1)(4)	13	4.5	1.00
	Alclad A93003	H14	0.010 to 0.500	21	(1)(3)(4)	19	16	1.00
B 210	A95050	O	0.018 to 0.500	21	(1)	18	6	1.00
	Alclad A95050	O	0.018 to 0.500	21	(1)(13)(23)	17	. . .	1.00
	A96061	T4	0.025 to 0.500	23	(1)(6)	30	16	1.00
	A96061	T6	0.025 to 0.500	23	(1)(6)	42	35	1.00
	A96061	T4, T6 welded	0.025 to 0.500	23	(1)(7)	24	10	1.00
Seamless Pipe and Seamless Extruded Tube								
B 241	A93003	O	All	21	(1)	14	5	1.00
	A93003	H18	Less than 1.000	21	(1)(3)	27	24	1.00
B 241	A93003	H112	Note (20)	21	(1)(3)(20)	14	5	1.00
	Alclad A93003	O	All	21	(1)(4)	13	4.5	1.00
	Alclad A93003	H112	All	21	(1)(3)(4)	13	4.5	1.00
B 241	A95083	O	All	25	(1)(8)	39	16	1.00
	A95083	H112	All	25	(1)(8)	39	16	1.00
	A95454	O	Up thru 5.000	22	(1)	31	12	1.00
	A95454	H112	Up thru 5.000	22	(1)	31	12	1.00
B 241	A96061	T4	All	23	(1)(6)(9)	26	16	1.00
	A96061	T6	Under 1 in. dia.	23	(1)(2)(5)	42	35	1.00
	A96061	T6	All	23	(1)(6)(9)	38	35	1.00
	A96061	T4, T6 welded	All	23	(1)(7)(9)	24	10	1.00
	A96063	T6	Note (10)	23	(1)(6)(10)	30	25	1.00
	A96063	T5, T6 welded	Note (10)	23	(1)(7)(10)	17	10	1.00
Drawn Seamless Condenser and Heat Exchanger Tube								
B 234	A93003	H14	0.010 to 0.200	21	(1)(2)	20	17	1.00
	Alclad A93003	H14	0.010 to 0.200	21	(1)(2)(4)	19	16	1.00
	A95454	H34	0.010 to 0.200	22	(1)(2)	39	29	1.00
B 234	A96061	T4	0.025 to 0.200	23	(1)(6)	30	16	1.00
	A96061	T6	0.025 to 0.200	23	(1)(6)	42	35	1.00
	A96061	T4, T6 welded	0.025 to 0.200	23	(1)(7)	24	10	1.00
Arc-Welded Round Tube								
B 547	A93003	O	0.125 to 0.500	21	(1)(15)	14	5	1.00
	A93003	O	0.125 to 0.500	21	(1)(16)	14	5	0.85
	A93003	H112	0.250 to 0.400	21	(1)(14)(15)	17	10	1.00
	A93003	H112	0.250 to 0.400	21	(1)(14)(16)	17	10	0.85
B 547	Alclad A93003	O	0.125 to 0.499	21	(1)(4)(15)	13	4.5	1.00
	Alclad A93003	O	0.125 to 0.499	21	(1)(4)(16)	13	4.5	0.85
	Alclad A93003	H112	0.250 to 0.499	21	(1)(4)(14)(15)	16	9	1.00
	Alclad A93003	H112	0.250 to 0.499	21	(1)(4)(14)(16)	16	9	0.85

Table C-1 (SI) Moduli of Elasticity for Ferrous Material (A08)

Material	E = Modulus of Elasticity, MPa (Multiply Tabulated Values by 10^3) [Note (1)]																	
	Temperature, °C																	
	−75	20	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800
Carbon steels with carbon content 0.30% or less	208	203	201	198	195	191	189	185	179	172	162	150	136	122	107	...	...	...
Carbon steels with carbon content above 0.30%	207	202	200	197	194	190	188	184	178	171	161	149	135	121	106	...	...	...
Carbon-moly steels	206	201	199	196	193	189	187	183	177	170	160	149	135	121	106	...	...	...
Nickel steels	196	192	190	187	184	180	178	174	169	162	153	141	128	115	101	...	...	...
Chromium steels:																		
$\frac{1}{2}$Cr through 2Cr	210	205	204	201	197	193	190	186	181	176	170	160	148	133	...	...	...	...
2$\frac{1}{4}$Cr through 3Cr	216	211	210	207	203	199	195	191	187	182	175	165	153	137	...	...	...	...
5Cr through 9Cr	219	213	212	209	205	201	197	193	189	185	181	176	171	164	156	147	138	...
Austenitic stainless steels: Type 304, 18Cr–8Ni Type 310, 25Cr–20Ni Type 316, 16Cr–12Ni–2Mo Type 321, 18Cr–10Ni–Ti Type 347, 18Cr–10Ni–Cb Type 309. 23Cr–12Ni	201	195	194	192	188	184	180	176	172	168	164	160	156	152	146	140	134	127
Straight chromium stainless steels (12Cr, 17Cr, 27Cr)	208	201	200	198	194	190	186	181	178	174	167	156	144	130	113	...	...	...
Gray cast iron	...	92	92	91	89	87	85	82	78	73	67	...	...	...	...	...	...	...

NOTE:

(1) These data are for information and it is not to be implied that materials are suitable for all the temperature ranges shown.

Table C-2 Moduli of Elasticity for Nonferrous Material

	E = Modulus of Elasticity, psi (Multiply Tabulated Values by 10^6) [Note (1)]												
	Temperature, °F												
Materials	−100	70	200	300	400	500	600	700	800	900	1,000	1,100	1,200
High Nickel Alloys													
N02200 (200)	30.9	30.0	29.3	28.8	28.5	28.1	27.8	27.3	26.7	26.1	25.5	25.1	24.5
N02201 (201)													
N04400 (400)	26.8	26.0	25.4	25.0	24.7	24.3	24.1	23.7	23.1	22.6	22.1	21.7	21.2
N06002 (X)	29.4	28.5	27.8	27.4	27.1	26.6	26.4	25.9	25.4	24.8	24.2	23.7	23.2
N06600 (600)	31.9	31.0	30.2	29.9	29.5	29.0	28.7	28.2	27.6	27.0	26.4	25.9	25.3
N06617 (617)	. . .	29.2	28.4	28.0	27.7	27.4	27.0	26.5	26.0	25.5	24.9	24.3	23.8
N06625 (625)	30.9	30.0	29.3	28.8	28.5	28.1	27.8	27.3	26.7	26.1	25.5	25.1	24.5
N08800 (800) (2)	29.4	28.5	27.8	27.4	27.1	26.6	26.4	25.9	25.4	24.8	24.2	23.8	23.2
N08810 (800H) (2)													
N10001 (B)	32.0	31.1	30.3	29.9	29.5	29.1	28.8	28.3	27.7	27.1	26.4	26.0	25.3
N06007 (G)	28.6	27.8	27.1	26.7	26.4	26.0	25.7	25.3	24.7	24.2	23.6	23.2	22.7
N06455 (C-4)	30.6	29.8	29.1	28.6	28.3	27.9	27.6	27.1	26.5	25.9	25.3	24.9	24.3
N08320 (20 Mod)	28.6	27.8	27.1	26.7	26.4	26.0	25.7	25.3	24.7	24.2	23.6	23.2	22.7
N10276 (C-276)	30.6	29.8	29.1	28.6	28.3	27.9	27.6	27.1	26.5	25.9	25.3	24.9	24.3
N10665 (B-2)	32.3	31.4	30.6	30.1	29.8	29.3	29.0	28.6	27.9	27.3	26.7	26.2	25.6
Aluminum and Aluminum Alloys													
A24430 (B443)	10.5	10.0	9.6	9.2	8.7	8.1	. . .	. . .	. . .	. . .	. . .	. . .	. . .
A91060 (1060)													
A91100 (1100)													
A93003 (3003)													
A93004 (3004)													
A96061 (6061)													
A96063 (6063)													
A95052 (5052)	10.7	10.2	9.7	9.4	8.9	8.3	. . .	. . .	. . .	. . .	. . .	. . .	. . .
A95154 (5154)													
A95454 (5454)													
A95652 (5652)													
A03560 (356)	10.8	10.3	9.8	9.5	9.0	8.3	. . .	. . .	. . .	. . .	. . .	. . .	. . .
A95083 (5083)													
A95086 (5086)													
A95456 (5456)													
Copper and Copper Alloys													
C83600	14.4	14.0	13.7	13.4	13.2	12.9	12.5	12.0	. . .	. . .	. . .	. . .	. . .
C92200													
C46400	15.4	15.0	14.6	14.4	14.1	13.8	13.4	12.8	. . .	. . .	. . .	. . .	. . .
C65500													
C95200													
C95400													
C11000	16.5	16.0	15.6	15.4	15.0	14.7	14.2	13.7	. . .	. . .	. . .	. . .	. . .

Table C-2 Moduli of Elasticity for Nonferrous Material (Cont'd)

	E = Modulus of Elasticity, psi (Multiply Tabulated Values by 10^6) [Note (1)]												
	Temperature, °F												
Materials	−100	70	200	300	400	500	600	700	800	900	1,000	1,100	1,200
Copper and Copper Alloys (Cont'd)													
C10200	17.5	17.0	16.6	16.3	16.0	15.6	15.1	14.5	...	...	...	...	...
C12000													
C12200													
C12500													
C14200													
C23000													
C61400													
C70600	18.5	18.0	17.6	17.3	16.9	16.6	16.0	15.4	...	...	...	...	...
C97600	19.6	19.0	18.5	18.2	17.9	17.5	16.9	16.2	...	...	...	...	...
C71000	20.6	20.0	19.5	19.2	18.8	18.4	17.8	17.1	...	...	...	...	...
C71500	22.7	22.0	21.5	21.1	20.7	20.2	19.6	18.8	...	...	...	...	...
Unalloyed Titanium													
Grades 1, 2, 3, 7, and 12	...	15.5	15.0	14.6	14.0	13.3	12.6	11.9	11.2	...	...	...	...

NOTES:

(1) These data are for information and it is not to be implied that materials are suitable for all the temperature ranges shown.

(2) For N08800 and N08810, use the following *E* values above 1200°F: at 1300°F, $E = 22.7$; at 1400°F, $E = 21.9$; at 1500°F, $E = 21.2 \times 10^6$ psi.

(A08)

Table C-2 (SI) Moduli of Elasticity for Nonferrous Material

	E = Modulus of Elasticity, MPa (Multiply Tabulated Values by 10^3) [Note (1)]																	
	Temperature, °C																	
Materials	−75	20	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800
High Nickel Alloys																		
N02200 (200) N02201 (201)	214	207	205	202	199	197	194	191	189	186	183	180	176	172	169	164	161	156
N04400 (400)	185	179	178	175	173	170	168	166	164	161	158	156	153	149	146	142	139	135
N06002 (X)	203	197	195	192	189	187	184	182	179	177	174	171	167	163	160	156	153	148
N06600 (600)	221	214	212	209	206	203	200	198	195	192	189	186	182	178	174	170	166	161
N06617 (617)	...	201	...	196	193	191	189	187	184	181	178	174	171	167	164	160	156	152
N06625 (625)	214	207	205	202	199	197	194	191	189	186	183	180	176	172	169	164	161	156
N08800 (800) N08810 (800H)	203	197	195	192	189	187	184	182	179	177	174	171	167	163	160	156	153	148
N10001 (B)	222	214	213	210	207	204	201	198	196	193	190	186	182	178	175	170	167	161
N06007 (G)	198	192	190	187	185	182	180	177	175	172	169	167	163	159	156	152	149	144
N06455 (C-4)	212	205	204	201	198	195	193	190	188	185	182	179	175	171	167	163	160	155
N08320 (20 Mod)	198	192	190	187	185	182	180	177	175	172	169	167	163	159	156	152	149	144
N10276 (C-276)	212	205	204	201	198	195	193	190	188	185	182	179	175	171	167	163	160	155
N10665 (B-2)	224	217	215	212	209	206	203	200	198	195	191	188	184	180	176	172	168	163
Aluminum and Aluminum Alloys																		
A24430 (B443) A91060 (1060) A91100 (1100) A93003 (3003) A93004 (3004) A96061 (6061) A96063 (6063)	72	69	68	66	63	61	57	52	46	...	...	...	...	...	...	...	...	...
A95052 (5052) A95154 (5154) A95454 (5454) A95652 (5652)	74	70	69	67	65	62	58	53	47	...	...	...	...	...	...	...	...	...
A03560 (356) A95083 (5083) A95086 (5086) A95456 (5456)	74	71	70	68	65	62	58	54	47	...	...	...	...	...	...	...	...	...
Copper and Copper Alloys																		
C83600 C92200	99	97	96	94	93	91	89	87	84	81	...	...	...	...	...	...	...	...
C46400 C65500 C95200 C95400	107	103	102	101	99	98	96	93	90	86	...	...	...	...	...	...	...	...
C11000	114	110	109	108	106	104	102	99	96	92	...	...	...	...	...	...	...	...
C10200 C12000 C12200 C12500 C14200 C23000 C61400	121	117	116	115	113	111	108	106	102	98	...	...	...	...	...	...	...	...

Table C-2 (SI) Moduli of Elasticity for Nonferrous Material (Cont'd)

(A08)

	E = Modulus of Elasticity, MPa (Multiply Tabulated Values by 10^3) [Note (1)]																	
	Temperature, °C																	
Materials	−75	20	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800
Copper and Copper Alloys (Cont'd)																		
C70600 C97600 C71000 C71500	128	124	123	121	119	117	115	112	108	104	...	...	...	...	...	...	...	...
Unalloyed Titanium																		
Grades 1, 2, 3, 7, and 12	...	107	106	103	100	97	92	88	84	79	75	71	...	...	...	...	...	...

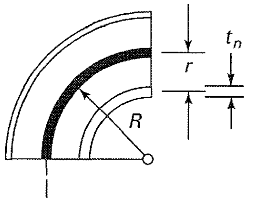
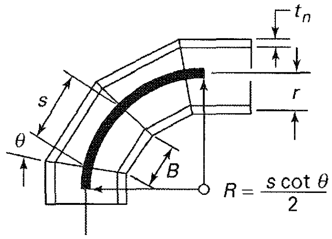
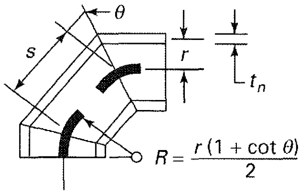
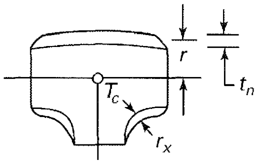
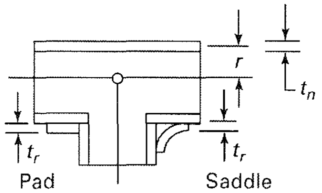
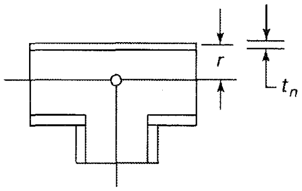
NOTE:

(1) These data are for information and it is not to be implied that materials are suitable for all the temperature ranges shown.

MANDATORY APPENDIX D

(07)

Table D-1 Flexibility and Stress Intensification Factors

Description	Flexibility Characteristic, h	Flexibility Factor, k	Stress Intensification Factor, i	Sketch
Welding elbow or pipe bend [Notes (1), (2), (3), (4), (5)]	$\dfrac{t_n R}{r^2}$	$\dfrac{1.65}{h}$	$\dfrac{0.9}{h^{2/3}}$	
Closely spaced miter bend [Notes (1), (2), (3), (5)] $s < r(1 + \tan\theta)$ $B \geq 6\,t_n$ $\theta \leq 22\frac{1}{2}$ deg	$\dfrac{s t_n \cot\theta}{2r^2}$	$\dfrac{1.52}{h^{5/6}}$	$\dfrac{0.9}{h^{2/3}}$	 t_n r s θ B $R = \dfrac{s \cot\theta}{2}$
Widely spaced miter bend [Notes (1), (2), (5), (6)] $s \geq r(1 + \tan\theta)$ $\theta \leq 22\frac{1}{2}$ deg	$\dfrac{t_n(1 + \cot\theta)}{2r}$	$\dfrac{1.52}{h^{5/6}}$	$\dfrac{0.9}{h^{2/3}}$	 θ s r t_n $R = \dfrac{r(1 + \cot\theta)}{2}$
Welding tee per ASME B16.9 [Notes (1), (2), (7)]	$\dfrac{3.1t_n}{r}$	1	$\dfrac{0.9}{h^{2/3}}$	
Reinforced fabricated tee [Notes (1), (2), (8), (9)]	$\dfrac{\left(t_n + \dfrac{t_r}{2}\right)^{5/2}}{r\,(t_n)^{3/2}}$	1	$\dfrac{0.9}{h^{2/3}}$	
Unreinforced fabricated tee [Notes (1), (2), (9)]	$\dfrac{t_n}{r}$	1	$\dfrac{0.9}{h^{2/3}}$	

MANDATORY APPENDIX F REFERENCED STANDARDS

(A08)

Specific editions of standards incorporated in this Code by reference are shown in this issue of Appendix F. It is not practical to refer to a specific edition of each standard throughout the Code text, but instead, the specific edition reference dates are shown here. Appendix F will be revised at intervals as needed and issued. The names and addresses of the sponsoring organizations are also shown in this issue.

American National Standard

Z223.1-1999

ASTM Specifications [Note (1)]

A 36/A 36M-00a
A 47/A 47M-99
A 48-94a$^{\epsilon1}$
A 53/A 53M-99b

A 105/A 105M-98
A 106-99$^{\epsilon1}$
A 125-96
A 126-95$^{\epsilon1}$
A 134-96
A 135-97c
A 139-00
A 178/A 178M-95
A 179/A 179M-90a
A 181/A 181M-00
A 182/A 182M-04
A 192/A 192M-91
A 193/A 193M-00a
A 194/A 194M-00a
A 197/A 197M-00

A 210/A 210M-96
A 213/A 213M-99a
A 214/A 214M-96
A 216/A 216M-93
A 217/A 217M-99
A 229/A 229M-99
A 234/A 234M-00
A 240/A 240M-04
A 242/A 242M-00a
A 249/A 249M-98
A 254-97
A 268/A 268M-00a
A 276-00a
A 278-93
A 283/A 283M-00
A 285/A 285M-90 (R96)
A 299/A 299M-97

ASTM Specifications [Note (1)] (Cont'd)

A 307-00
A 312/A 312M-00c
A 320/A 320M-00b
A 322-91 (R96)
A 333/A 333M-99
A 335/A 335M-00
A 336/A 336M-99
A 350/A 350M-00b
A 351/A 351M-00
A 354-00a
A 358/A 358M-00
A 369/A 369M-00
A 376/A 376M-00a
A 377-99
A 387/A 387M-99
A 389/A 389M-93 (R98)
A 395/A 395M-99

A 403/A 403M-00b
A 409/A 409M-95a
A 420/A 420M-00a
A 426-92 (R97)
A 437/A 437M-00a
A 449-00
A 450/A 450M-96a
A 451-93 (R97)
A 453/A 453M-00
A 479/A 479M-00

A 515/A 515M-92V
A 516/A 516M-90 (R96) (R97)
A 530/A 530M-99
A 564/A 564M-99
A 575-96
A 576-90b (R00)
A 587-96

A 671-96
A 672-96
A 691-98

A 714-99

ASTM Specifications [Note (1)] (Cont'd)

A 789/A 789M-04a
A 790/A 790M-04a

A 815-99

A 928-98
A 992-02

B 26/B 26M-99
B 32-00
B 42-98
B 43-98
B 61-93
B 62-93
B 68-99
B 68M-99
B 75-99
B 88-99
B 88M-99

B 108-99
B 111-98
B 111M-98
B 148-97
B 150-98
B 150M-95a
B 151/B 151M-00
B 161-00
B 163-98a
B 165-93
B 166-04
B 167-04
B 168-04
B 171-04

B 209-00
B 210-00
B 210M-00
B 221-00
B 234-00
B 234M-00
B 241/B 241M-00

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(A08)

Referenced Standards (Cont'd)

ASTM Specifications [Note (1)] (Cont'd)

B 247-00
B 247M-00
B 251-97
B 251M-97
B 265-99
B 280-99
B 283-99a

B 302-00
B 315-99
B 338-99
B 348-00
B 361-95
B 366-04b
B 367-93 (R98)
B 381-00

B 407-96
B 408-96
B 409-96a
B 423-99
B 424-98a
B 425-99
B 435-03
B 443-93
B 444-94
B 446-93
B 462-04
B 463-99
B 464-99
B 466/B 466M-98
B 467-88 (R97)
B 468-99
B 473-96

B 546-04
B 547/B 547M-00
B 564-00a
B 572-03
B 584-00

B 608-95
B 619-05
B 622-04a
B 625-99
B 626-04
B 649-95
B 673-96
B 674-96
B 675-02
B 676-03
B 677-99
B 688-96 (R04)
B 690-02

ASTM Specifications [Note (1)] (Cont'd)

B 691-95

B 704-91
B 705-94
B 729-00

B 804-02
B 828-00
B 861-00
B 862-99

ASTM Standard Test Methods

D 323-99
E 94-00
E 125-63 (R85)
E 186-91
E 280-93
E 446-91

MSS Standard Practices

SP-6-96
SP-9-97
SP-25-98
SP-42-90
SP-43-91
SP-45-98
SP-51-91
SP-53-95
SP-54-95
SP-55-96
SP-58-93
SP-61-92
SP-67-95
SP-68-97
SP-69-96
SP-75-98
SP-79-92
SP-80-97
SP-83-01
SP-89-98
SP-93-87
SP-94-92
SP-95-00
SP-97-95
SP-105-96
SP-106-03

AWS Specifications

A3.0-94
QC1-88

API Specification

5L, 38th Edition, 1990

ASME Codes & Standards

Boiler and Pressure Vessel Code, 2001 Edition, including Addenda

B1.1-1989
B1.13M-2001
B1.20.1-1983 (R01) (ANSI/ASME B1.20.1)
B1.20.3-1976 (R98) (ANSI B1.20.3)
B16.1-1998
B16.3-1998
B16.4-1998
B16.5-1996
B16.9-2001
B16.10-2000
B16.11-2001
B16.14-1991
B16.15-1985 (R94) (ANSI/ASME B16.15)
B16.18-1984 (R94) (ANSI B16.18)
B16.20-1998
B16.21-1992
B16.22-1995
B16.24-2001
B16.25-1997
B16.34-1996 (98A)
B16.42-1998
B16.47-1996 (98A)
B16.48-1997
B16.50-2001

B18.2.1-1996 (99A)
B18.2.2-1987 (R99) (ASME/ANSI B18.2.2)
B18.2.3.5M-1979 (R01)
B18.2.3.6M-1979 (R01)
B18.2.4.6M-1979 (R98)
B18.21.1-1999
B18.22M-1981
B18.22.1-1965 (R98)

B31.3-2002
B31.4-2002
B31.8-1999
B36.10M-2000
B36.19M-1985 (R94) (ANSI/ASME B36.19M)

TDP-1-1998

Referenced Standards (Cont'd) (A08)

AWWA and ANSI/AWWA Standards

C110/A21.10-98
C111/A21.11-95
C115/A21.15-99
C150/A21.50-96
C151/A21.51-96
C153/A21.53-94

C200-97
C207-94
C208-96

AWWA and ANSI/AWWA Standards (Cont'd)

C300-97
C301-99
C302-95
C304-99

C500-93(95a)
C504-94
C509-94

C600-99
C606-97

National Fire Codes

NFPA 54/ANSI Z223.1-06
NFPA 85-04
NFPA 1963-03

PFI Standards

ES-16-94
ES-24-98

FCI Standard

79-1-03

GENERAL NOTE: The issue date shown immediately following the hyphen after the number of the standard (e.g., B1.1-1989, A 36-89, SP-6-96) is the effective date of issue (edition) of the standard. B18.2.2-1987 (R99) designates specification reaffirmed without change in 1999.

NOTE:
(1) For boiler external piping material application, see para. 123.2.2.

Specifications and standards of the following organizations appear in this Appendix:

AISC American Institute of Steel Construction, Inc.
One East Wacker Drive
Chicago, IL 60601-1802

ANSI American National Standards Institute
25 West 43rd Street
New York, NY 10036
Phone: 212 642-4900

API American Petroleum Institute
1220 L Street, NW
Washington, DC 20005-4070
Phone: 202 682-8000

ASME The American Society of Mechanical Engineers
Three Park Avenue
New York, NY 10016-5990

ASME Order Department
22 Law Drive
Box 2300
Fairfield, NJ 07007-2300
Phone: 201 882-1167
800-THE-ASME (US & Canada)
Fax: 201 882-1717, 5155

ASTM American Society for Testing and Materials
100 Barr Harbor Drive
P.O. Box C700
West Conshohocken, PA 19428-2959
Phone: 610 832-9585
Fax: 610 832-9555

AWS American Welding Society
550 NW LeJeune Road
Miami, FL 33126
Phone: 305 443-9353

AWWA American Water Works Association
6666 W. Quincy Avenue
Denver, CO 80235
Phone: 303 794-7711

FCI Fluid Controls Institute, Inc.
1300 Sumner Avenue
Cleveland, OH 44115-2851
Phone: 216 241-7333
Fax: 216 241-0105

MSS Manufacturers Standardization Society of the Valve and Fittings Industry, Inc.
127 Park Street, NE
Vienna, VA 22180-4602
Phone: 703 281-6613

NFPA National Fire Protection Association
1 Batterymarch Park
Quincy, MA 02169-7471
Phone: 617 770-3000
Fax: 617 770-0700

PFI Pipe Fabrication Institute
666 Fifth Avenue, No. 325
New York, NY 10103
Phone: 514 634-3434

PPI Plastics Pipe Institute
1825 Connecticut Avenue, NW
Suite 680
Washington, DC 20009
Phone: 202 462-9607
Fax: 202 462-9779

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MANDATORY APPENDIX G
NOMENCLATURE

This Appendix is a compilation of the nomenclature used within this Code. Included are the term definitions and units that can be uniformly applied. These terms are also defined at a convenient location within the Code. When used elsewhere within the Code, definitions given here shall be understood to apply.

		Units		References	
Symbol	Definition	SI	U.S.	Paragraph	Table/Fig./App.
A	Corrosion, erosion, and mechanical allowances (including threading, grooving)	mm	in.	104.1.2(A)[eqs. (3), (3A), (4), (4A)] 104.3.1(D.2) 104.3.1(G) 104.4.1(B) 104.5.2(B)[eq. (6)] 104.5.3(A)	104.3.1(G)
Area available for reinforcement:					
A_1	in run pipe	mm^2	in.^{2}	104.3.1(D.2.3) 104.3.1(G.6)	104.3.1(D) 104.3.1(G)
A_2	in branch pipe	mm^2	in.^{2}	104.3.1(D.2.3) 104.3.1(G.6)	104.3.1(D) 104.3.1(G)
A_3	by deposited metal beyond outside diameter of run and branch and for fillet weld attachments of rings, pads, and saddles	mm^2	in.^{2}	104.3.1(D.2.3)	104.3.1(D)
A_4	by reinforcing ring, pad, or integral reinforcement	mm^2	in.^{2}	104.3.1(D.2.3) 104.3.1(G.6)	104.3.1(D) 104.3.1(G)
A_5	in saddle on right angle connection	mm^2	in.^{2}	104.3.1(D.2.3)	104.3.1(D)
A_6	Pressure design area expected at the end of service life	mm^2	in.^{2}	104.3.1(D.2)	104.3.1(D)
A_7	Required reinforcement area	mm^2	in.^{2}	104.3.1(D.2.2) 104.3.1(G.5)	104.3.1(D) 104.3.1(G)
B	Length of miter segment at crotch	mm	in.	104.3.3(A&B)	App. D, Table D-1
b	Subscript referring to branch	. . .	. . .	104.3.1(D.2)	104.3.1(D)
C	Cold-spring factor	. . .	. . .	119.10.1[eqs. (9), (10)]	. . .
C_x	Size of fillet weld for socket welding components other than flanges	mm	in.	. . .	127.4.4(C)
c	Flanged elbow correction factor	. . .	. . .	. . .	Table D-1 Chart D-2
D	Nominal pipe size	mm	in.	119.7.1(A.3)	. . .
D	Outside diameter of run pipe	mm	in.	104.3.1(G.4) 104.3.1(G.5)	104.3.1(G)

Symbol	Definition	Units		References	
		SI	U.S.	Paragraph	Table/Fig./App.
$D_{1,2}$	Outside diameter of reducer	mm	in.	. . .	App. D, Table D-1
D_n	Nominal outside diameter of pipe	mm	in.	102.3.2(D)	. . .
D_o	Outside diameter of pipe	mm	in.	102.3.2(D) 104.1.2(A)[eqs. (3), (4)] 104.8.1[eqs. (11A), (11B)] 104.8.2[eqs. (12A), (12B)]	App. D, Table D-1 104.1.2(A)[eq. (5)]
D_{ob}	Outside diameter of branch	mm	in.	104.3.1(D.2) 104.3.1(D.2.3) 104.3.1(E) 104.3.1(G.4) 104.3.1(G.5)	App. D, Fig. D-1 104.3.1(G)
D_{oh}	Outside diameter of header or run pipe	mm	in.	104.3.1(D.2) 104.3.1(E) 104.3.1(G.4) 104.3.1(G.5)	104.3.1(G)
d	Inside diameter of pipe	mm	in.	104.1.2(A)[eqs. (3A), (4A), (5)]	104.1.2(A)
d_1	Inside centerline longitudinal direction of the finished branch opening in the run of the pipe	mm	in.	104.3.1(D) 104.3.1(E)	104.3.1(D)
d_2	Half-width of reinforcement zone	mm	in.	104.3.1(D.2)	104.3.1(D)
d_5	Diameter of finished opening	mm	in.	104.4.2	. . .
d_6	Inside or pitch diameter of gasket	mm	in.	104.5.3(A)[eq. (7)]	104.5.3
d_b	Corroded internal diameter of branch pipe	mm	in.	104.3.1(G.4)	104.3.1(G)
d_c	Corroded internal diameter of extruded outlet	mm	in.	104.3.1(G.4) 104.3.1(G.5) 104.3.1(G.6)	104.3.1(G)
d_i	Inside diameter of Y-globe valve	mm	in.	. . .	122.1.7(C)
d_n	Nominal inside diameter of pipe	mm	in.	102.3.2(D)	. . .
d_r	Corroded internal diameter of run	mm	in.	104.3.1(G.4)	104.3.1(G)
E	Weld joint efficiency factor	. . .	. . .	104.1.2(A.5)	102.4.3 App. A Notes and Tables
E	Young's modulus of elasticity (used with subscripts)	MPa	psi	119.6.2 119.6.4 119.10.1[eqs. (9), (10)]	App. C, Tables C-1 and C-2 App. D, Table D-1
F	Casting quality factor	. . .	. . .	104.1.2(A.5)	App. A Notes and Tables

Symbol	Definition	Units		References	
		SI	U.S.	Paragraph	Table/Fig./App.
f	Stress range reduction factor	. . .	. . .	102.3.2(C)[eq. (1)] 104.8.3[eqs. (13A), (13B)]	102.3.2(C)
h	Subscript referring to run or header	. . .	. . .	104.3.1(D.2)	104.3.1(D) 104.3.1(G)
h	Thread depth (ref. ASME B1.20.1)	mm	in.	102.4.2	. . .
h	Flexibility characteristic, to compute i, k	. . .	. . .	. . .	App. D, Table D-1
h_o	Height of extruded lip	mm	in.	104.3.1(G.2) 104.3.1(G.4)	104.3.1(G)
I	Lorenz equation compensation factor	. . .	. . .	102.4.5[eqs. (3B), (3C), (3D), (3E)]	. . .
i	Stress intensification factor	. . .	. . .	104.8.1[eqs. (11A), (11B)] 104.8.2[eqs. (12A), (12B)] 104.8.3[eqs. (13A), (13B)] 104.8.4(C)	App. D, Table D-1
j	Subscript for resultant moment	. . .	. . .	104.8.4(A)	. . .
K	Factor for reinforcing area	. . .	. . .	104.3.1(G.5)	104.3.1(G)
k	Factor for occasional loads	. . .	. . .	104.8.2[eqs. (12A), (12B)]	. . .
k	Flexibility factor	. . .	. . .	. . .	App. D, Table D-1
L	Developed length of line axis	m	ft	119.7.1(A.3)	. . .
L_1	Height of nozzle	mm	in.	104.8.4(C)	App. D, Fig. D-1
L_4	Altitude of reinforcing zone outside run pipe	mm	in.	104.3.1(D.2)	104.3.1(D)
L_8	Altitude of reinforcing zone for extruded outlet	mm	in.	104.3.1(G.4) 104.3.1(G.6)	104.3.1(G)
M	Moment of bending or torsional force (used with subscripts to define applications as shown in referenced paragraphs)	mm·N	in.-lb	104.8.1[eqs. (11A), (11B)] 104.8.2[eqs. (12A), (12B)] 104.8.3[eqs. (13A), (13B)] 104.8.4(A) 104.8.4(C)	104.8.4
MAWP	Maximum allowable working pressure	kPa	psi	100.2	. . .
MSOP	Maximum sustained operating pressure	kPa	psi	101.2.2	. . .
N	Equivalent full temperature cycles	. . .	. . .	102.3.2(C)[eq. (2)]	102.3.2(C)

Symbol	Definition	Units		References	
		SI	U.S.	Paragraph	Table/Fig./App.
N_E	Number of cycles of full temperature change	. . .	. . .	102.3.2(C)[eq. (2)]	. . .
N_n	Number of cycles of lesser temperature change, $n = 1, 2, \ldots$	. . .	. . .	102.3.2(C)[eq. (2)]	. . .
NPS	Nominal pipe size	. . .	in.	General	. . .
P	Internal design gage pressure of pipe, component	kPa	psi	102.3.2(D) 104.1.2(A)[eqs. (3), (3A), (4), (4A)] 104.5.1(A) 104.5.2(B) 104.5.3(A)[eq. (7)] 104.5.3(B) 104.8.1[eqs. (11A), (11B)] 104.8.2[eqs. (12A), (12B)] 122.1.2(A) 122.1.3(A) 122.1.4(A) 122.1.4(B) 122.1.6(B) 122.1.7(C) 122.4(B)	App. D, Table D-1
q	Ratio of partial ΔT to maximum ΔT (used with subscripts)	. . .	. . .	102.3.2(C)[eq. (2)]	. . .
R	Reaction moment in flexibility analysis (used with subscripts)	mm-N	in.-lb	119.10.1[eqs. (9), (10)]	. . .
R	Centerline radius of elbow or bend, and effective "radius" of miter bends	mm	in.	102.4.5(B) 104.3.3(C.3.1)	App. D, Table D-1 102.4.5
R_m	Mean radius of run pipe	mm	in.	. . .	App. D, Fig. D-1 App. D, Table D-1
r	Mean radius of pipe using nominal wall t_n	mm	in.	104.3.3	App. D, Table D-1
r_1	Half width of reinforcement zone	mm	in.	104.3.1(G.4)	104.3.1(G)
r_1, r_2, r_3	Transition radii of branch reinforcement	mm	in.	. . .	App. D, Fig. D-1
r_b	Branch mean cross-sectional radius	mm	in.	104.8.4	. . .
r_i	Inside radius of branch	mm	in.	104.8.4(C)	App. D, Fig. D-1
r'_m	Mean radius of branch	mm	in.	104.8.4(C)	App. D, Fig. D-1 App. D, Table D-1
r_o	Radius of curvature of external curved portion	mm	in.	104.3.1(G.2) 104.3.1(G.4) 104.3.1(G.6)	104.3.1(G)
r_p	Outside radius of branch reinforcement	mm	in.	. . .	App. D, Fig. D-1 App. D, Table D-1

Symbol	Definition	Units		References	
		SI	U.S.	Paragraph	Table/Fig./App.
r_x	External crotch radius of welded-in contour inserts	mm	in.	. . .	App. D
S	Basic material allowable stress	MPa	psi	122.1.2(A) 122.1.3(B) 122.4(B.3)	. . .
S	Basic material allowable stress	MPa	ksi	102.3.1(A)	App. A Tables and Notes
S_a	Bolt design stress at atmospheric temperature	kPa	psi	104.5.1(A)	. . .
S_b	Bolt design stress at design temperature	kPa	psi	104.5.1(A)	. . .
S_c	Basic material allowable stress at minimum (cold) temperature	MPa	psi	102.3.2(C)[eq. (1)]	. . .
S_f	Allowable stress for flange material or pipe	kPa	psi	104.5.1(A)	. . .
S_h	Basic material allowable stress at maximum (hot) temperature	MPa	psi	102.3.2(C)[eq. (1)] 102.3.2(D) 104.8.1[eqs. (11A), (11B)] 104.8.2[eqs. (12A), (12B)] 104.8.3[eqs. (13A), (13B)] 119.10.1 [eq. (10)]	. . .
S_{lp}	Longitudinal pressure stress	kPa	psi	102.3.2(D) 104.8	. . .
S_A	Allowable stress range for expansion stress	MPa	psi	102.3.2(C)[eq. (1)] 104.8.3[eqs. (13A), (13B)]	. . .
S_E	Computed thermal expansion stress range	MPa	psi	104.8.3[eqs. (13A), (13B)] 119.6.4 119.10.1[eq. (10)]	. . .
S_L	Longitudinal stress due to pressure, weight, and other sustained loads	MPa	psi	102.3.2(D) 104.8.1[eqs. (11A), (11B)] 104.8.3[eqs. (13A), (13B)]	. . .
SE	Allowable stress (including weld joint efficiency factor)	MPa	psi	102.3.2(C) 104.1.2(A)[eqs. (3), (3A), (4), (4A)] 104.5.2(B) 104.5.3(A)[eq. (7)] 104.5.3(B)	. . .
SE	Allowable stress (including weld joint efficiency factor)	MPa	ksi	102.3.1(A)	App. A Tables and Notes
SF	Allowable stress (including casting quality factor)	MPa	psi	104.1.2(A)	. . .

		Units		References	
Symbol	Definition	SI	U.S.	Paragraph	Table/Fig./App.
SF	Allowable stress (including casting quality factor)	MPa	ksi	102.3.1(A)	App. A Tables and Notes
s	Miter spacing pipe centerline	mm	in.	. . .	App. D, Table D-1
T	Pipe wall thickness (measured or minimum, in accordance with purchase specification used with or without subscripts), viz., T_b = thickness of branch T_h = thickness of header, etc.	mm	in.	104.3.1(D.2) 104.8.4(C)	104.3.1(D) App. D, Fig. D-1
T_c	Crotch thickness of welded-in contour inserts	mm	in.	. . .	App. D, Table D-1
T_o	Corroded finished thickness extruded outlet	mm	in.	104.3.1(G.4) 104.3.1(G.6)	104.3.1(G)
t	Pressure design thickness pipe, components (used with subscripts)	mm	in.	104.1.2(A)[eqs. (3), (3A), (4), (4A)] 104.3.1(D.2) 104.3.1(G.4) 104.3.3(C.3.1) 104.3.3(C.3.2) 104.4.1(B) 104.4.2 104.5.2(B)[eq. (6)] 104.5.3(A)[eq. (7)] 104.5.3(B) 104.8.1 104.8.4(C) 127.4.8(B) 132.4.2(E)	104.3.1(G) 104.5.3 127.4.8(D)
$t_{1,2}$	Nominal wall thickness of reducer	mm	in.	. . .	App. D, Table D-1
t_b	Required thickness of branch pipe	mm	in.	104.3.1(G.4) 104.3.1(G.6)	104.3.1(G)
t_c	Throat thickness of cover fillet weld, branch connection	mm	in.	127.4.8(B) 132.4.2(E)	127.4.8(D)
t_e	Effective branch wall thickness	mm	in.	104.8.4(C)	. . .
t_h	Required thickness of header or run	mm	in.	104.3.1(G.4)	104.3.1(G)
t_m	Minimum required thickness of component, including allowances (c) for mechanical joining, corrosion, etc. (used with subscripts), viz., t_{mb} = minimum thickness of branch t_{mh} = minimum thickness of header	mm	in.	104.1.2(A)[eqs. (3), (3A), (4), (4A)] 104.3.1(D.2) 104.3.1(E) 104.3.1(G) 104.3.3(C.3.1) 104.3.3(C.3.2) 104.4.1(B) 104.5.2(B)[eq. (6)] 104.5.3(A)	102.4.5 104.1.2(A) 104.3.1(D) 104.3.1(G) 127.4.2

		Units		References	
Symbol	Definition	SI	U.S.	Paragraph	Table/Fig./App.
t_n	Nominal wall thickness of component (used with subscripts), viz., t_{nb} = nominal wall thickness of branch t_{nh} = nominal wall thickness of header t_{nr} = nominal thickness of reinforcement	mm	in.	102.3.2(D) 104.3.1(G) 104.3.3 104.8.1[eqs. (11A), (11B)] 104.8.2[eqs. (12A), (12B)] 104.8.4(C) 127.4.8(B) 132.4.2(E)	127.4.4(B) 127.4.4(C) 127.4.8(D) App. D, Fig. D-1 App. D, Table D-1
t_r	Thickness of reinforcing pad or saddle	mm	in.	104.3.1(D.2) 104.3.1(E)	104.3.1(D) App. D, Table D-1
t_s	Wall thickness of segment or miter	mm	in.	104.3.3(C.3)	. . .
t_w	Weld thickness	mm	in.	104.3.1(C.2)	127.4.8(F)
U	Anchor distance (length of straight line joining anchors)	m	ft	119.7.1(A.3)	. . .
W	Weld strength reduction factor	. . .	. . .	102.4.7 104.1.4	102.4.7
$x_{\min}$	Size of fillet weld for slip-on and socket welding flanges or socket wall for socket welds	mm	in.	. . .	127.4.4(B)
Y	Resultant of movement to be absorbed by pipelines	. . .	. . .	119.7.1(A.3)	. . .
y	A coefficient having values given in Table 104.1.2(A)	. . .	. . .	104.1.2(A.7)[eqs. (3), (3A), (4), (4A), (5)]	104.1.2(A) App. A, Notes to Tables A-4, A-5, A-6, A-7, and A-9
y	Branch offset dimension	mm	in.	. . .	App. D, Fig. D-1
Z	Section modulus of pipe	mm^3	in.^3	104.8.1[eqs. (11A), (11B)] 104.8.2[eqs. (12A), (12B)] 104.8.3[eqs. (13A), (13B)] 104.8.4(A) 104.8.4(C)	. . .
α	Angle between axes of branch and run	deg	deg	104.3.1(D.2) 104.3.1(E)	104.3.1(D)
α	Reducer cone angle	deg	deg	. . .	App. D, Table D-1
δ	Mismatch or offset	mm	in.	. . .	App. D, Table D-1
ΔT	Range of temperature change (used with subscripts)	°C	°F	102.3.2(C)	. . .
θ	Angle of miter cut	deg	deg	104.3.3	App. D, Table D-1
θ_n	Transition angle of branch reinforcement	deg	deg	. . .	App. D., Fig. D-1
$\geq$	Equal to or greater than	. . .	. . .	. . .	. . .
$\leq$	Equal to or less than	. . .	. . .	. . .	. . .

Table III-4.2.3 Hydrostatic Design Basis (HDB) for Machine-Made Reinforced Thermosetting Resin Pipe

ASTM Spec. No. and Type	Grade	Class	Material Designation ASTM D 2310	HDB Stress [Note (1)] at 73°F [Notes (2), (3)] Cyclic, ksi [Note (4)]	HDB Stress [Note (1)] at 73°F [Notes (2), (3)] Static, ksi [Note (5)]
D 2517 filament wound	Glass fiber reinforced epoxy resin	No liner	RTRP-11AD	5.0	. . .
			RTRP-11AW	. . .	16.0
D 2996 filament wound	Glass fiber reinforced epoxy resin	No liner	RTRP-11AD	5.0	. . .
			RTRP-11AW	. . .	16.0
		Epoxy resin liner, reinforced	RTRP-11FE	6.3	. . .
			RTRP-11FD	5.0	. . .
	Glass fiber reinforced polyester resin	Polyester resin liner, reinforced	RTRP-12EC	4.0	. . .
			RTRP-12ED	5.0	. . .
			RTRP-12EU	. . .	12.5
		No liner	RTRP-12AD	5.0	. . .
			RTRP-12AU	. . .	12.5
D 2997 centrifugally cast	Glass fiber reinforced polyester resin	Polyester resin liner, nonreinforced	RTRP-22BT	. . .	10.0
			RTRP-22BU	. . .	12.5
		Epoxy resin liner, nonreinforced	RTRP-21CT	. . .	10.0
			RTRP-21CU	. . .	12.5

NOTES:
(1) A service (design) factor must be applied to these HDB values to obtain the HDS.
(2) These HDB values apply only at 73°F.
(3) Recommended temperature limits for these materials are shown in Table III-4.2.2.
(4) When using the cyclic design basis, the service factor shall not exceed 1.0.
(5) When using the static design basis, the service factor shall not exceed 0.5.

BPS that personnel of his organization will use. Subject to the specific approval of the designer, a BPS qualified by others may be used if the following conditions apply:

(C.1.1) The designer accepts that the proposed qualified BPS has been prepared and executed by a responsible recognized organization with expertise in the field of bonding.

(C.1.2) The designer accepts both the BPS and Procedure Qualification Record (PQR) by signature as his own.

(C.1.3) The piping erector has at least one bonder, currently employed, who has satisfactorily passed a performance qualification test using the proposed qualified BPS.

(C.2) Bonding Performance Qualification. A piping erector shall not accept a performance qualification test made by a bonder or bonding operator for another piping erector without the designer's specific approval. If approval is given, acceptance is limited to performance qualification tests on piping using the same or an equivalent BPS. The piping erector accepting such performance qualification tests shall obtain a copy of the PQR from the previous erector, showing the name of the piping erector by whom bonders or bonding operators were qualified, the dates of such qualification, and the date the bonder or bonding operator last assembled pressure piping under the previous performance qualification.

(D) Qualification tests for the bonding procedure and operator performance shall comply with the requirements of the BPS and the following:

(D.1) A test assembly shall be fabricated in accordance with the bonding procedure specification. The test

(A08)

Table III-4.3.1 Thermal Expansion Coefficients, Nonmetals

Material Description	Mean Coefficients			
	10^{-6} in./in./°F	Range, °F	10^{-6} mm/mm/°C	Range, °C
Thermoplastics				
PVC, Type 1120	30	23–37	54	−5 to +3
PVC, Type 2116	40	37–45	72	3–7
CPVC 4120	34	. . .	61	. . .
PE, Type 2406	90	. . .	162	. . .
PE, Type 3408	90	70–120	162	21–49
Polypropylene	43	. . .	77	. . .
Poly(vinylidine chloride)	85	. . .	153	. . .
Poly(vinylidine fluoride)	100	. . .	180	. . .
Reinforced Thermosetting Resins				
Epoxy-glass, centrifugally cast	9–13	. . .	16–23.5	. . .
Epoxy-glass, filament-wound	9–13	. . .	16–23.5	. . .
Polyester-glass, centrifugally cast	9–15	. . .	16–27	. . .
Polyester-glass, filament-wound	9–11	. . .	16–20	. . .
Polyester-glass, hand lay-up	12–15	. . .	21.5–27	. . .
Other				
Hard rubber (Buna N)	40	. . .	72	. . .

GENERAL NOTE: Values in this Table are representative. Values at actual design temperature shall be obtained from the manufacturers.

(A08) **Table III-4.3.2 Modulus of Elasticity, Nonmetals**

Material Description	*E*, ksi (73.4°F) [Note (1)]	*E*, MPa (23°C) [Note (1)]
Thermoplastics		
PVC, Type 1120	420	2 895
PVC, Type 2116	360	2 485
CPVC 4120	420	2 895
PE, Type 2406	90	620
PE, Type 3408	110	740
Polypropylene	120	825
Poly(vinylidene/chloride)	100	690
Poly(vinylidene fluoride)	194	1 340
Thermosetting Resins, Axially Reinforced		
Epoxy-glass, centrifugally cast	1,200–1,900	8 725–13 100
Epoxy-glass, filament-wound	1,100–2,000	7 585–13 790
Polyester-glass, centrifugally cast	1,200–1,900	8 275–13 100
Polyester-glass, filament-wound	1,000–2,000	6 895–13 790
Polyester-glass, hand lay-up	800–1,000	5 515–6 895
Other		
Hard rubber (Buna N)	300	2 070

NOTE:

(1) The modulus of elasticity values for thermosetting resin pipe are given in the longitudinal direction; different values may apply in the circumferential or hoop direction. The modulus of elasticity values for thermoplastic resin pipe are temperature-dependent and stress-time related. In all cases for materials listed in this Table, manufacturers shall be consulted for specific product information.

assembly shall consist of at least one pipe-to-pipe joint and one pipe-to-fitting joint. The size of the pipe used for the test assembly shall be as follows:

(D.1.1) When the largest size to be joined (within the BPS) is 4 in. NPS or smaller, the test assembly shall be the same NPS as the largest size to be joined.

(D.1.2) When the largest size to be joined within the BPS is greater than 4 in. NPS, the test assembly shall be made of piping components either 4 in. NPS or a minimum of 25% of the NPS of the largest piping component to be joined, whichever is larger.

(D.2) The test assembly shall be subjected to one of the following qualification test operations.

(D.2.1) When the test assembly has been cured, it shall be subjected to a hydrostatic pressure test of the maximum of either 150 psig or 1.5 times an equivalent allowable pressure which shall be calculated using the least nominal wall thickness and outside diameter of the pipe in the test assembly. This pressure shall be determined using the equation in para. III-2.2.2(A) for the test material. The test shall be conducted so that the joint is loaded in both the circumferential and longitudinal directions. Joints shall not leak or separate when tested.

(D.2.2) When a test assembly is joined by heat fusion, the fusion joints may be tested by cutting a minimum of three coupons containing the joint and bending the strips using a procedure which shall be defined in the BPS. As a minimum requirement, the test strips shall not break when bent a minimum of 90 deg, at ambient temperature, over an inside bend radius of 1.5 times the nominal diameter of the tested pipe.

(E) Performance Requalification

(E.1) Renewal of a bonding performance qualification is required when

(E.1.1) a bonder or bonding operator has not used the specific bonding process for a period of time greater than 6 months, or a specific maximum period of time otherwise permitted in the BPS for the work

(E.1.2) there is a specific reason to question a bonder or bonding operator's ability to make bonds that meet the BPS

(E.2) Renewal of a bonding performance qualification for a specific bonding process may be made in only a single test assembly.

(F) Qualification Records. An erector using bonders, or bonder operators, shall maintain a record of the procedures used and of operators employed by him who are qualified in these procedures.

III-5.1.3 Thermoplastic Joints

(A) Solvent-Cemented Joints

(A.1) Preparation. PVC and CPVC surfaces to be cemented shall be cleaned by wiping with a clean cloth moistened with acetone or methylethyl ketone. Cleaning for ABS shall conform to ASTM D 2235. Cuts shall be free of burrs and circumferential cuts shall be as square as those obtained by the use of a saw with a miter box or a square-end sawing vise. A slight interference fit between the pipe and a fitting socket is preferred, and the diametral clearance between a pipe and the entrance of a mating socket shall not exceed 0.04 in. This fit shall be checked before solvent cementing.

(A.2) Procedure. Joints shall be made in accordance with a qualified BPS. ASTM D 2855 provides a suitable basis for such a procedure. Solvent cements for PVC, CPVC, and ABS shall conform to ASTM D 2564, D 2846, and D 2235, respectively. Cement shall be applied to both joint surfaces. The amount of cement shall be sufficient to

Fig. III-5.1.3(A) Solvent-Cemented Joint

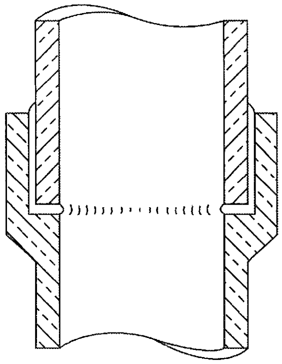
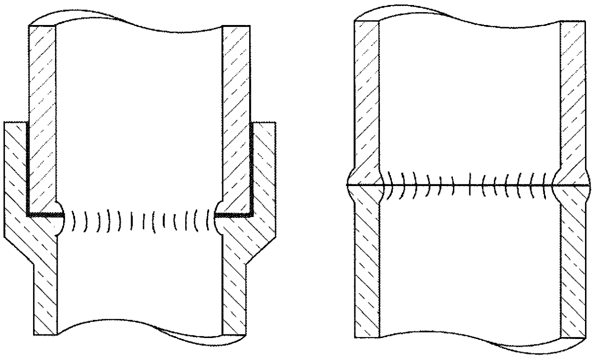


Fig. III-5.1.3(B) Heat Fusion Joints


Socket Joint

Butt Joint

produce a small continuous fillet of cement at the outer limits of the joints. See Fig. III-5.1.3(A).

(A.3) Branch Connections. For branch connections not using a tee, a manufactured full reinforcement saddle with an integral branch socket shall be solvent cemented to the run pipe over its entire contact surface.

(A.4) Limitations on Imperfections. Imperfections exceeding the following limitations are considered defects and shall be repaired and reexamined in accordance with para. III-5.1.5:

(A.4.A) protrusion of dried cement exceeding 50% of pipe wall thickness into the bore of the pipe

(A.4.B) unfilled or unbonded areas in a joint as indicated by the lack or interruption of the continuous fillet noted in (A.2) above

(B) Heat Fusion Joints

(B.1) Preparation. Surfaces to be heat fused together shall be cleaned of any foreign material. Cuts shall be free of burrs, and circumferential cuts shall be as square as those obtained by the use of a saw with a miter box or a square-end sawing vise.

(B.2) Procedure. Joints shall be made in accordance with a qualified BPS. The general procedures in ASTM D 2657, Technique I-Socket Fusion, II-Butt Fusion, and III-Saddle Fusion provide a suitable basis for such a procedure. Both surfaces to be joined shall be uniformly heated to produce a continuous homogeneous bond between them. This will produce a small continuous fillet of fused material at the outer limits of the joints. See Fig. III-5.1.3(B).

(B.3) Branch Connections. Branch connections shall be made only with the use of molded fittings in sizes that are commercially available.

(B.4) Limitations on Imperfections. Imperfections exceeding the following limitations are considered defects and shall be repaired and reexamined in accordance with para. III-5.1.5:

(B.4.A) protrusion of fused material exceeding 25% of the pipe wall thickness into the bore of the pipe

(B.4.B) unfilled or unbonded areas in a joint as indicated by the lack or interruption of the continuous fillet noted in (B.2) above

(C) Electrofusion Joints

(C.1) Preparation. Surfaces to be heat fused together shall be cleaned of all foreign material.

(C.2) Procedure. Joints shall be made in accordance with the qualified BPS. The general procedures in ASTM F 1290, "Technique 1 — Coupling Procedure" and "Technique 2 — Saddle Procedure," provide a suitable basis for the development of such a procedure. See Fig. III-5.1.3(C).

III-5.1.4 Thermosetting Resin Joints

(A) Preparation. Cutting of pipe and preparation of bonding surfaces shall be done, as recommended by the manufacturer, without chipping or cracking of the cut ends; particularly, the inner surface of centrifugally cast pipe. Pipe may be preheated, if necessary, to comply with the above requirements. Cuts shall be free of burrs, and circumferential cuts shall be as square as required by the purchaser's specifications or the recommendations of the manufacturer, whichever requires the closer squareness. For branch connections, holes in the run pipe may be made with a hole saw. Mold release agent and any other material which may interfere with adhesion shall be removed from surfaces to be bonded.

(B) Joining Procedures

(B.1) Socket and Spigot Joints. Joints shall be made in accordance with a qualified BPS based on the manufacturer's recommended procedure. Application of adhesive to the surfaces to be joined, and assembly of those surfaces shall produce a continuous bond between them. Cut ends of the pipe and edges of the laminate fabric shall be sealed to prevent fluid penetration of the pipe wall or the laminate material.

(B.2) Butt-and-Wrap Joints. Joints shall be made in accordance with a qualified BPS. The general procedures in ASTM C 582, Contact-Molded Reinforced Thermosetting Plastic (RTP) Laminates for Corrosion Resistant

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ASME B31.1
INTERPRETATIONS VOLUME 43

Replies to Technical Inquiries
January 1, 2007 Through December 31, 2007

FOREWORD

It has been agreed to publish interpretations issued by the B31 Committee concerning B31.1 as part of the update service to the Code. The interpretations have been assigned numbers in chronological order. Each interpretation applies either to the latest Edition or Addenda at the time of issuance of the interpretation or the Edition or Addenda stated in the reply. Subsequent revisions to the Code may have superseded the reply.

The replies are taken verbatim from the original letters, except for a few typographical and editorial corrections made for the purpose of improved clarity. In some instances, a review of the interpretation revealed a need for corrections of a technical nature. In these cases, a revised reply bearing the original interpretation number with the suffix R is presented. In the case where an interpretation is corrected by errata, the original interpretation number with the suffix E is used.

ASME procedures provide for reconsideration of these interpretations when or if additional information is available which the inquirer believes might affect the interpretation. Further, persons aggrieved by an interpretation may appeal to the cognizant ASME committee or subcommittee. As stated in the Statement of Policy in the Code documents, ASME does not "approve," "certify," "rate," or "endorse" any item, construction, proprietary device, or activity.

For the 2007 Edition, interpretations will be issued as necessary up to twice a year until the publication of the 2010 Edition.

The page numbers for the Interpretation supplements included with updates to the 2007 Edition start with I-1 and will continue consecutively through the last update to this Edition.

B31.1

Subject	Interpretation	File No.
Applicability of B31.1 for Piping in a Gas-Cooled Nuclear Power Plant	43-3	06-1173
Owner	43-5	03-744
Para. 104.8.2, Stress Due to Occasional Loads	43-4	05-1275
Para. 136, Visual Examination	43-6	07-752
Para. 137.4, Hydrostatic Testing	43-2	06-1144
Use of Other Code for Nonboiler External Piping Design, Fabrication, and Inspection	43-1	03-670

Interpretation: 43-1

Subject: B31.1-2001, Use of Other Code for Nonboiler External Piping Design, Fabrication, and Inspection

Date Issued: January 10, 2007

File: 03-670

Question: Does the B31.1 Code allow the design, fabrication, and inspection of nonboiler external piping to a different Code Section, such as B31.3?

Reply: Yes. The Introduction to the B31.1 Code states "It is the owner's responsibility to select the B31 Code Section which most nearly applies to a proposed piping installation. Factors to be considered by the owner include: limitations of the Code Section, jurisdictional requirements, and the applicability of other codes and standards. All applicable requirements of the selected Code Section shall be met. For some installations, more than one Code Section may apply to different parts of the installation. The owner is also responsible for imposing requirements supplementary to those of the selected Code Section, if necessary, to assure safe piping for the proposed installation."

Interpretation: 43-2

Subject: B31.1-1995, Para. 137.4, Hydrostatic Testing

Date Issued: February 14, 2007

File: 06-1144

Question (1): Does B31.1 require a piping system to be completely filled with water or other acceptable test medium prior to hydrostatic testing?

Reply (1): Yes, to the extent possible using high point vents or other venting methods per para. 137.4.2.

Question (2): Does B31.1 have any requirements or limits regarding the addition of test medium during the hydrostatic test pressurization?

Reply (2): No.

Interpretation: 43-3

Subject: Applicability of B31.1 for Piping in a Gas-Cooled Nuclear Power Plant

Date Issued: February 14, 2007

File: 06-1173

Question: With consideration of "limitations of the Code Section, jurisdictional requirements, and the applicability of other codes and standards," does B31.1 prohibit the owner from selecting B31.1 as the applicable Code Section for design and construction of primary heat transfer piping in a gas-cooled nuclear power plant?

Reply: No. Refer to the Introduction for additional information.

Interpretation: 43-4

Subject: B31.1-2004, Para. 104.8.2, Stress Due to Occasional Loads

Date Issued: May 3, 2007

File: 05-1275

Question: In accordance with the Code para. 101.1, when a piping system operates at multiple sets of coincident operating temperatures and pressures, and the system may at random be loaded with an occasional load as defined in para. 102.3.3, may the maximum allowable stress used in para. 104.8.2 equations (12A) and (12B) be based on the corresponding temperature for each set of loading conditions that could occur?

Reply: Yes.

Interpretation: 43-5

Subject: B31.1-2004, Owner

Date Issued: June 11, 2007

File: 03-744

Question: Does the ASME B31.1-2004 Edition define the term "owner"?

Reply: No.

Interpretation: 43-6

Subject: B31.1-2004, Para. 136, Visual Examination

Date Issued: October 4, 2007

File: 07-752

Question (1): Is it required that flaws which are found using nonrequired radiography, but which could have been found during visual observation of an incomplete weld, meet the acceptance criteria of para. 136.4.2(A)?

Reply (1): No; the acceptance standards given in para. 136.4.2(A) only apply to completed welds.

Question (2): Is it required that flaws found during radiography, which is not required, meet the acceptance criteria of para. 136.4.5(A)?

Reply (2): The acceptance criteria for nonrequired examinations are not given by the Code. See Interpretation 37-2 of B31.1.

B31.1 — Cases No. 33

A Case is the official method of handling a reply to an inquiry when study indicates that the Code wording needs clarification, or when the reply modifies the existing requirements of the Code or grants permission to use new materials or alternative constructions.

ASME has agreed to publish Cases issued by the B31 Committee concerning B31.1 as part of the update service to B31.1. The text of proposed new and revised Cases and reaffirmations of current Cases appear on the ASME website at http://cstools.asme.org/csconnect/CommitteePages.cfm for public review. New and revised Cases, as well as announcements of reaffirmed Cases and annulments, then appear in the next update. As of the 1992 and later editions, all Cases currently in effect at the time of publication of an edition are included with it as an update.

The ASME B31 Code for Pressure Piping Standards Committee took action to eliminate Code Case expiration dates effective September 21, 2007. This means that all Code Cases listed in this update and beyond will remain available for use until annulled by the ASME B31 Code for Pressure Piping Standards Committee.

This update, Cases No. 33, which is included after the last page of the 2008 Addenda and the Interpretations Volume 43 that follow, contains the following Cases:

175 176 177 179 182 183

The page numbers for the Cases supplements included with updates to the 2007 Edition start with C-1 and will continue consecutively through the last update to this Edition. The Cases affected by this supplement are as follows:

Page	*Location*	*Change*
C-15	Case 175	Expiration date eliminated
C-17	Case 176	Expiration date eliminated
C-19	Case 177	Expiration date eliminated
C-20	Case 179	Expiration date eliminated
C-21	Case 182	Expiration date eliminated
C-23	Case 183	Expiration date eliminated

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B31 CASE 175
ASTM B 16 (UNS C36000) and B 453 (UNS C35300) in ASME B31.1 Construction

Approval Date: September 12, 2003

Reaffirmation Date: August 7, 2007

Inquiry: May brass alloys rods and bars conforming to ASTM B 16 (UNS C36000) and B 453 (UNS C35300) be used for ASME B31.1 construction?

Reply: It is the opinion of the Committee that brass alloys rods and bars conforming to ASTM B 16 (UNS C36000) and B 453 (UNS C35300) may be used for B31.1 construction provided:

(a) These materials shall not be used for boiler external piping except where specifically permitted by Section I. See para. 100.1.2(A).

(b) The maximum permissible design temperature shall not exceed 406°F (208°C).

(c) The maximum permissible size of finished product shall not exceed NPS 3.

(d) These materials shall not be welded.

(e) These materials shall be used only in the soft anneal (O60) temper.

(f) Limitations for use of these materials for flammable liquids and gases shall be in accordance with paras. 122.7, 122.8, and 124.7.

(g) Material conforming to ASTM B 16 alloy UNS C36000 shall not be used in primary pressure relief valve applications.

(h) A representative finished model of each product size and design shall be tested to determine the presence of residual stresses which might result in failure of individual parts due to stress corrosion cracking. Tests shall be conducted in accordance with ASTM B 154 or ASTM B 858M.

(i) Materials shall be tested to determine the presence of residual stresses which might result in failure of individual parts due to stress corrosion cracking. Tests shall be conducted in accordance with ASTM B 154 or ASTM B 858M. The test frequency shall be as specified in B 249.

(j) Heat treatment after fabrication or forming is neither required nor prohibited.

(k) The allowable stress values shown in Table 1 shall apply. These allowable stress values are based on a tensile strength factor of safety 4.0. These stress values may be interpolated to determine values for intermediate temperatures.

(l) The specified minimum tensile and yield strengths shown in Table 1 shall apply.

(m) This Case number shall be referenced in the documentation and marking of the material and recorded on the Manufacturer's Data Report.

Table 1

Element	Heat Analysis Limit, % Wt.
Carbon	0.20 max.
Manganese	1.00 max.
Silicon	0.80 max.
Phosphorus	0.030 max.
Sulfur	0.010 max.
Chromium	19.50 to 20.50
Nickel	17.50 to 18.50
Molybdenum	6.0 to 6.5
Nitrogen	0.18 to 0.22
Iron [Note (1)]	Balance

NOTE:

(1) Element shall be determined arithmetically by difference.

Table 2 Maximum Allowable Stress Values in Tension, ksi

Spec. No.	P-No.	*E*	−20 to 100	200	300	400	500	600	650	700	750
Bar											
A 479	8	1.00	23.5	23.5	21.4	19.9	18.5	17.9	17.7	17.5	17.3
A 479 [Note (1)]	8	1.00	23.5	23.5	22.4	21.3	20.5	20.1	19.9	19.9	19.8
Fittings, WP and WP-WX											
A 403	8	1.00	23.5	23.5	21.4	19.9	18.5	17.9	17.7	17.5	17.3
A 403 [Note (1)]	8	1.00	23.5	23.5	22.4	21.3	20.5	20.1	19.9	19.9	19.8
Fittings, WP-W and WP-WU											
A 403	8	0.85	20.0	20.0	18.2	16.9	15.7	15.2	15.0	14.9	14.7
A 403 [Note (1)]	8	0.85	20.0	20.0	19.0	18.1	17.4	17.1	16.9	16.9	19.8

GENERAL NOTES:

(a) Minimum tensile strength = 94 ksi.

(b) Minimum yield strength = 44 ksi.

NOTE:

(1) Due to the relatively low yield strength of these materials, these higher stress values were established at temperatures where the short-time tensile properties govern to permit the use of these alloys where slightly greater deformation is acceptable. The stress values in this range exceed 66⅔% but do not exceed 90% of the yield strength at temperature. Use of these stresses may result in dimensional changes due to permanent strain. These stress values are not recommended for the flanges of gasketed joints or other applications where slight amounts of distortion can cause leakage or malfunction.

Table 3 Product Specification

Spec. No.	Product Type
A 403	Fittings, seamless and welded
A 479	Bar

B31 CASE 177
Alternate Rules for Preheat of P-No. 5B Materials

Approval Date: September 12, 2003

Reaffirmation Date: August 7, 2007

Inquiry: May the nominal preheat temperature for P-No. 5B materials be reduced to 200°F, during root examination, without performing an intermediate heat treatment as required by para. 131.6.1(C)?

Reply: Yes, the preheat temperature for P-No. 5B materials may be reduced to 200°F (minimum) during root examination without performing an intermediate heat treatment as required by para. 131.6.1(C), provided the following conditions are met:

(a) a minimum of at least $^3/_8$ in. thickness of weld is deposited or 25% of the welding groove is filled, whichever is less (the weldment shall be sufficiently supported to prevent overstressing the weld if the weldment is to be moved or otherwise loaded)

(b) after cooling to 200°F minimum, and before welding is resumed, visual examinations of the weld shall be performed to assure that no cracks have formed

(c) the required preheat of para. 131.4.5 shall be applied before welding is resumed

B31 CASE 179
Use of Ultrasonic Examination in Lieu of Radiography for B31.1 Applications in Materials $\frac{1}{2}$ in. and Less in Wall Thickness

Approval Date: June 28, 2006

Inquiry: Under what conditions and limitations may an ultrasonic examination be used in lieu of radiography on fabrication welds in materials with a thickness of $\frac{1}{2}$ in. or less when a volumetric examination is required by Table 136.4 of ASME B31.1?

Reply: Welds in pressure piping governed by the ASME Code for Pressure Piping, B31.1, may be examined using the ultrasonic (UT) method in lieu of radiography (RT) at any time, provided that all of the following requirements are met:

(a) the ultrasonic examination is performed using an ultrasonic system capable of recording the ultrasonic examination data to facilitate the analysis by a third party and for the repeatability of subsequent examinations, should they be required

(b) personnel performing and evaluating UT examinations shall be qualified and certified in accordance with their employer's written practice and the requirements of para. 136.3.2 of the ASME Code for Pressure Piping, B31.1

(c) personnel, procedures, and equipment used to collect and analyze UT data shall have demonstrated their ability to perform an acceptable examination using test blocks approved by the Owner

(d) welds that are shown by ultrasonic examination to have discontinuities that produce an indication greater than 20% of the reference level shall be investigated to the extent that ultrasonic examination personnel can determine their shape, identity, and location, so that they may evaluate each discontinuity for acceptance in accordance with (1) and (2) below.

(1) Discontinuities evaluated as being cracks, lack of fusion, or incomplete penetration are unacceptable regardless of length.

(2) Other discontinuities are unacceptable if the indication exceeds the reference level and their length exceeds the following:

(a) $\frac{1}{4}$ in. (6.0 mm) for t up to $\frac{3}{4}$ in. (19.0 mm)

(b) $\frac{1}{3}t$ for t from $\frac{3}{4}$ in. (19.0 mm) to $2\frac{1}{4}$ in. (57.0 mm)

(c) $\frac{3}{4}$ in. (19.0 mm) for t over $2\frac{1}{4}$ in. (57.0 mm)

where t is the thickness of the weld being examined. If the weld joins two members having different thicknesses at the weld, t is the thinner of these two thicknesses.

B31 CASE 182
Use of 1.15Ni–0.65Cu–Mo–Cb in ASME B31.1 Construction

Approval Date: November 10, 2006

Inquiry: May A 335-05a P36 Class 1 and Class 2, and A 182-05a F36 Class 1 and Class 2, be used for B31.1 construction?

Reply: It is the opinion of the Committee that A 335-05a P36 Class 1 and Class 2, and A 182-05a F36 Class 1 and Class 2, may be used for B31.1 construction provided that all of the following requirements are met:

(a) All applicable requirements of ASME B31.1 shall be met.

(b) The maximum allowable stress values and other data shown in Table 1 or 1M apply.

(c) Separate weld procedure and performance qualifications shall apply for both classes of this material. The postweld heat treatment of the Class 1 and Class 2 material shall be in accordance with the rules specified in Table 2 or 2M.

(d) After either cold bending to strains in excess of 5% or any hot bending of this material, the full length of the component shall be heat treated in accordance with the requirements specified in the material specification. (See PG-19 of Section I for method for calculating strain.)

(e) Postweld heat treatment is mandatory under all conditions.

(f) This Case number shall be referenced in the documentation and marking of the material, and recorded on the Manufacturer's Data Report (if applicable).

CAUTIONARY NOTE: **Corrosion fatigue occurs by the combined actions of cyclic loading and a corrosive environment. In piping systems, corrosion fatigue is more likely to occur in portions of water systems with low strain rates (< 1.0%/sec), higher temperatures [above 300°F (150°C)], and higher dissolved oxygen (> 0.04 ppm), with a preference toward regions with increased local stresses. While the mechanisms of crack initiation and growth are complex and not fully understood, there is consensus that the two major factors are strain and waterside environment. Strain excursions of sufficient magnitude to fracture the protective oxide layer play a major role. In terms of the waterside environment, high levels of dissolved oxygen and pH excursions are known to be detrimental. Historically, the steels applied in these water-touched components have had the minimum specified yield strengths in the range of 27 ksi to 45 ksi (185 MPa to 310 MPa) and minimum specified tensile strengths in the range of 47 ksi to 80 ksi (325 MPa to 550 MPa). As these materials are supplanted by higher strength steels, some have concern that the higher design stresses and thinner wall thicknesses will render components more vulnerable to failures by corrosion fatigue. Thus, when employing such higher strength steels for water systems, it is desirable to use "best practices" in design by minimizing localized strain concentrations, in control of water chemistry and during lay-up by limiting dissolved oxygen and pH excursions, and in operation by conservative startup, shutdown, and turndown practices.**

Table 1 Maximum Allowable Stress Values

For Metal Temperature Not Exceeding, °F	Maximum Allowable Stress Values, ksi	
	Class 1	Class 2
–20 to 100	25.7	27.3
200	25.7	27.3
300	25.1	26.6
400	25.1	26.6
500	25.1	26.6
600	25.1	26.6
700	25.1	26.6

Table 1M Maximum Allowable Stress Values

For Metal Temperature Not Exceeding, °C	Maximum Allowable Stress Values, MPa	
	Class 1	Class 2
–30 to 40	177	188
100	177	188
150	173	183
200	173	183
250	173	183
300	173	183
350	173	183
371	173	183

Table 2 Requirements for Postweld Heat Treatment (PWHT)

Class	PWHT Temperature, °F	Holding Time
1	1,100–1,200	2 in. and less thickness: 1 hr/in., 15 min minimum Over 2 in.: add 15 min for each additional inch of thickness
2	1,000–1,150	1 hr/in., ½ hr min.

Table 2M Requirements for Postweld Heat Treatment (PWHT)

Class	PWHT Temperature, °C	Holding Time
1	595–650	50 mm and less thickness: 1 hr/25 mm, 15 min minimum Over 50 mm: add 15 min for each additional 25 mm of thickness
2	540–620	1 hr/25 mm, ½ hr min.

B31 CASE 183
Use of Seamless 9Cr–2W in ASME B31.1 Construction

Approval Date: April 26, 2007

Inquiry: May seamless 9Cr–2W tubes, pipes, and forgings, with the chemical analysis shown in Table 1 and minimum mechanical properties as shown in Table 2 that otherwise conform to the specifications listed in Table 3, be used for ASME B31.1 construction?

Reply: It is the opinion of the Committee that seamless 9Cr–2W tubes, pipes, and forgings, with the chemical analysis shown in Table 1 and minimum mechanical properties as shown in Table 2 that otherwise conform to the specifications listed in Table 3, may be used for ASME B31.1 construction provided the following requirements are met:

(a) The material shall be austenitized within the temperature range of 1,900°F to 1,975°F (1 040°C to 1 080°C), followed by air cooling or accelerated cooling, and tempered within the range of 1,350°F to 1,470°F (730°C to 800°C).

(b) The material shall not exceed a Brinell hardness number of 250 (Rockwell C 25).

(c) The maximum allowable stress values for the material shall be those given in Table 4. Maximum temperature of application shall be limited to 1,150°F (621°C), except that tubing used in applications up to and including $3\frac{1}{2}$ in. (89 mm) outside diameter may be used up to 1,200°F (649°C).

(d) Separate weld procedure qualification shall be conducted. For the purpose of performance qualifications, the material shall be considered P-No. 5B, Group 2. The procedure and performance qualifications shall be conducted in accordance with Section IX. Postweld heat treatment for this material is mandatory, and the following rules shall apply:

(1) The time requirements shall be those given for P-No. 5B, Group 2 materials in Table 132.

(2) The PWHT temperature range shall be 1,350°F to 1,470°F (730°C to 800°C).

(e) Except as provided in paragraph (f), if during the manufacturing any portion of the component is heated to a temperature greater than 1,470°F (800°C), then the component must be reaustenitized and retempered in its entirety in accordance with paragraph (a), or that portion of the component heated above 1,470°F (800°C), including the heat-affected zone created by the local heating, must be replaced, or must be removed, reaustenitized, and retempered, and then replaced in the component.

(f) If the allowable stress values to be used are less than or equal to those provided in Table 1A of Section II, Part D for Grade 9 (SA-213 T9, SA-353 P9, or equivalent product specifications) at the design temperature, then the requirements of paragraph (e) may be waived, provided that the portion of the component heated to a temperature greater than 1,470°F (800°C) is reheat treated within the temperature range 1,350°F to 1,425°F (730°C to 775°C).

(g) This Case number shall be shown on the Manufacturer's Data Report.

(h) This Case number shall be shown in the material certification and marking of the material.

Table 1 Chemical Requirements

Element	Composition Limits, %
Carbon	0.07–0.13
Manganese	0.30–0.60
Phosphorus, max.	0.020
Sulfur, max.	0.010
Silicon, max.	0.50
Chromium	8.50–9.50
Molybdenum	0.30–0.60
Tungsten	1.50–2.00
Nickel, max.	0.40
Vanadium	0.15–0.25
Columbium	0.04–0.09
Nitrogen	0.030–0.070
Aluminum, max.	0.02
Boron	0.001–0.006
Titanium, max.	0.01
Zirconium, max.	0.01

Table 2 Mechanical Property Requirements

Property	Min. Value
Tensile strength	90 ksi
Yield strength	64 ksi
Elongation in 2 in. [Note (1)]	20%

NOTE:

(1) For longitudinal strip tests, a deduction from the basic values of 1.00% for each $\frac{1}{32}$-in. decrease in wall thickness below $\frac{5}{16}$ in. shall be made. Below are the computed minimum elongation values for each $\frac{1}{32}$-in. decrease in wall thickness. Where the wall thickness lies between two values shown below, the minimum elongation value shall be determined by the following equation:

$$E = 32t + 10.0$$

where

E = elongation in 2 in., %
t = actual thickness of specimen, in.

Wall Thickness, in.	Elongation in 2 in., min., %
$\frac{5}{16}$ (0.312)	20.0
$\frac{9}{32}$ (0.281)	19.0
$\frac{1}{4}$ (0.250)	18.0
$\frac{7}{32}$ (0.219)	17.0
$\frac{3}{16}$ (0.188)	16.0
$\frac{5}{32}$ (0.156)	15.0
$\frac{1}{8}$ (0.125)	14.0
$\frac{3}{32}$ (0.094)	13.0
$\frac{1}{16}$ (0.062)	12.0
0.062 to 0.035, excl.	11.6
0.035 to 0.022, excl.	10.9
0.022 to 0.015, incl.	10.6

Table 3 Specifications

Product Form	Spec. No.
Forgings	SA-182
Forged pipe	SA-369
Pipe	SA-335
Tube	SA-213

Table 4 Maximum Allowable Stress Values for Tube and Pipe

For Metal Temperature Not Exceeding, °F	Maximum Allowable Stress Values, ksi	
	Tube	Forgings, Pipe, Forged Pipe
−20 to 100	25.7	25.7
200	25.7	25.7
300	25.3	25.3
400	24.5	24.5
500	23.8	23.8
600	23.2	23.2
650	22.8	22.8
700	22.4	22.4
750	21.9	21.9
800	21.4	21.4
850	20.8	20.8
900	20.1	20.1
950	19.2	19.2
1,000	18.3	18.3
1,050	16.1	15.7
1,100	12.3	12.0
1,150	8.9	8.6
1,200	5.9	5.6

GENERAL NOTE: The allowable stress values are based on the revised criterion for tensile strength at temperature divided by 3.5, where applicable.

ASME CODE FOR PRESSURE PIPING, B31

Power Piping	B31.1-2007
Fuel Gas Piping	B31.2[1]-1968
Process Piping	B31.3-2006
Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids	B31.4-2006
Refrigeration Piping and Heat Transfer Components	B31.5-2006
Gas Transmission and Distribution Piping Systems	B31.8-2007
Managing System Integrity of Gas Pipelines	B31.8S-2004
Building Services Piping	B31.9-2004
Slurry Transportation Piping Systems	B31.11-2002
Manual for Determining the Remaining Strength of Corroded Pipelines: A Supplement to ASME B31 Code for Pressure Piping	B31G-1991
Standard Test Method for Determining Stress Intensification Factors (*i*-Factors) for Metallic Piping Components	B31J-2008
Pipeline Personnel Qualification	B31Q-2006

NOTE:

(1) USAS B31.2-1968 was withdrawn as an American National Standard on February 18, 1988. ASME will continue to make available USAS B31.2-1968 as a historical document for a period of time.

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